EFFECT OF PHOSPHORUS APPLICATION ON THE GROWTH AND YIELD OF SWEET POTATOES IN EMBU WEST SUB-COUNTY

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work, and has not been presented to any other university for any award.

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DEDICATION

To my late Dad Dominic Mugai, my son, daughter, mum and sister, you were the greatest source of my strength all through.

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My most sincere tribute goes to the almighty God for this far that he has brought me. Secondly, my profound gratitude goes to the chairman of the department Dr. David Mushimiyimana, and my supervisor Dr. Mworia Mugambi for their support, guidance and tireless efforts. May God bless you abundantly.

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ABSTRACT

Sweet potato is among the drought-resistant crops that take a short period to mature. Therefore, sweet potato plays a significant role in food security in Kenya because of its high degree of flexibility. Embu West Sub County's main economic activity is agriculture, which is the economic pillar of Embu County. Most farmers at the grassroots level have not been able to access proper fertilization on their farms because of a lack of adequate and authentic knowledge. This study focused on the sweet potato fertilization regime, especially the application of phosphorous. The of study's objectives were; to determine the yield potential of three sweet potato varieties, to determine the effect of P levels on growth and yield of sweet potatoes and to evaluate the effect of interaction between the sweet potato varieties and P levels. The study was carried out in Embu west at KARLO EMBU farm in two different seasons season 1 during the long rains (April to September2016) while season 2 was carried out during the short rains (November 2016 to April 2017). Land was cleared, dug and harrowed to fine tilth manually. Using RCBD, land was divided into three blocks. Each block had twelve plots each measuring three meters by three meters. Each plot received a combination of two treatments that is sweet potato variety and a specific level of P. Treatments was randomly assigned on the experimental units. The sweet potato varieties used were SPK004(V1), Kenspot 3(V2) and Kenspot 4(V3).The P fertilizer levels used were 0 kg/ha(P1), 25 kg/ha(P2), 50 kg/ha(P3), and 75 kg/ha(P4). Data on specific growth and yield parameters was collected throughout the study period, the collected data was summarized using excel. SPSS version 23 was used for ANOVA, at α=0.05.For treatment means that were significantly different LSD as Post hoc test was used to separate them. The study showed significant yield potential difference in all yield parameters among the three sweet potato varieties with Kenspot 4 being the highest producer of both marketable tubers yield and biomass above the ground. The study showed that the amount of P applied significantly affect growth and yield of sweet potatoes with a P level of 50 kg/ha being the recommended rate. According to this study, interaction between the variety of sweet potatoes and the P levels applied had no significant influence on the growth and yield of sweet potato.

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LIST OF ABBREVIATIONS

ASALs	Arid and Semi-Arid Lands
CIP	International Potato Centre
CIRAD	French Agricultural Research Centre For international Development
CM	Chicken Manure
DAO	District Agricultural Officer
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FYM	Farmyard Manure
GoK	Government of Kenya
IDCCS	Inter Diocesan Christian Community Services
K	Potassium
K_2O	Potassium oxide
KALRO	Kenya Agricultural Livestock Research Organization
KARI	Kenya Agricultural Research Institute
N	Nitrogen
NAAIAP	National Accelerated Input Access Programme
OFSP	Orange Fleshed Sweet potato

P	Phosphorus
PBZ	Paclobutrazol
P_2O_5	Phosphorus pentoxide
PN	Net photosynthetic Rate
PUE	Phosphoric Utilization Efficiency
RCBD	Randomized Complete Block Design
SPFMV	Sweet Potato Feathery Mottle Virus
SSA	Sub Saharan Africa
SSA	Sub Saharan Africa
SSP	Single Super Phosphate
UNCTAD	United Nations Conference on Trade and Development

CHAPTER ONE: INTRODUCTION

1.0 STUDY BACKGROUND

Sweet potato is a nutritive root crop that holds significant quantities of roughage, beta carotene and vitamin C, mostly in cultivars with greatly colored roots. Sweet potato is also a treasured source of vitamins A, B, and E, and it holds reasonable intensities of iron and zinc (Kareem et al., 2020; Kays, 2016; Brandenberger et al., 2014). In the world, Asia produces the highest quantity of sweet potato per year, producing 88.51 million tons. China produces around 76% of the world's sweet potato product, thus it is the top producer of sweet potato in the world (Tavva & Nedunchezhiyan, 2012). China is the topmost supplier of sweet potato (82,474,410 tons) (Food and Agriculture Organization of the United Nations [FAO], 2012).

Among the six very essential food crops, sweet potato is ranked as the sixth after rice, wheat, potatoes, maize and cassava. It is however ranked the fifth key food crop in the developing countries (FAO, 2015). Production data for the sweet potato in the world have not changed for over the past 40 years hence do not show a hopeful picture. The total production has stagnated at roughly 137 million metric tons, despite the fact that the total number of people in the world has in actual fact doubled up (Kays, 2016). As opined by FAO (2015) the sweet potato is avoided a favorite source of food by many people despite the escalating world's population. The reason for avoiding sweet potato consumption is not because farmers are not able to grow it, since it has the ability to give high quantity of produce, it is highly nutritious and it can do well in a wide range of soil and environment.

Reasonably, serious limitations seem to be constraining use which in turn prevent increase in production.

Sweet potato can grow at height above sea level ranging from 0 -2,500 meters. It requires smaller quantity of inputs and less labor than other crops such as maize, and put up with marginal growing circumstances (e.g., dry spells, poor soil) (Oswald et al., 2009). Many farmers in the world are gradually seeing the importance of producing sweet potato As postulated by Lirag (2019) sweet potato is trading well in the worldwide market, doing better in terms of trade outperforming other main food crops because its desirable for consumption by man and it's also a fast source of earnings .

Over the same time interval, the produce/ha has enhanced for each of the crops, particularly for sweet potato but there has been a simultaneous drop in the hectarage of sweet potato grown initiating the overall production to stagnate (FAO, 2012). Various reasons can cause the Yields of sweet potato to differ considerably including location, soil factors, climate and crop's genetic constitution. Under ultimate settings, very great harvests can be achieved, but more probable harvests will vary between 300 to 350 bushels (bushel=50 lbs.) per acre (Brandenberger et al., 2014). In the USA 22.8 tons per hectare were recorded while Japan, produced a weight of 21.7 tons per hectare (FAO, 2015).In sub-Saharan Africa, yields obtained are normally less than 10 tons per hectare wet weight (FAO, 2015).

When choosing the variety to plant, various factors should be considered including what consumers prefer, how much they can resist pests, the quality of produce and their ability to produce propagation materials for slip production (Monostori & Szarvas, 2015). As with all vegetal crops, marketplace demand is a great aspect in choosing a cultivar to produce, and the possibility for a cultivar to give high yields. New varieties should also be tried on the farms first before being introduced to farmers after which farmers should try them so that they can be able to judge whether they should adopt them or not. To produce the maximum produce, sweet potato should be planted at a PH range of between 5.8-6.0.they are however tolerant to a PH of between5.5-6.8. Lime should be applied to lower the soil PH. Sweet potatoes take up about 49.94kg of N, 6.81kg of P and 49.94kg of K per acre from the soil (Brandenberger et al., 2014).

Among the macronutrients, in many soils, nitrogen is the first nutrient whose deficiency limits growth of plants followed by phosphorus. Phosphorus as a major nutrient facilitates transmission of energy in cells, photosynthesis, and respiration and is a constituent of nucleic acid nucleotides, phospholipids and phosphorylated sugars (Muindi, 2019; Plenet et al., 2000). Regrettably in soils found in the dry areas that characterize the tropics, phosphorus accessibility by plants is very low and this limits agricultural production in those areas. (Kochian et al., 2004).

In many soils, despite the fact that fertilizers containing an ample amount of P are constantly added, the quantity of phosphorus that the plants can reach is mostly low because phosphorus is many a times converted to a state that is not available to plants since it reacts with other soil elements (El Sayed et al., 2011). Crops which are planted in soils that are deficient of phosphorus have a lower total leaf area, which negatively affect light capture by the leaves eventually lowering growth rate of plants (Plenet et al., 2000). There is clue showing that the photosynthetic rate goes down in plants that either do not get any P from the soil or those that get very little (Yong-fu, 2006). The reduction in speed of photosynthesis per unit leaf area in then affects the Net Assimilation Rate (NAR) and, eventually growth speed in plants.

Sweet potato requires a great amount of phosphorus for maximum production and growth so if planted in soils that lack phosphorus, sizeable losses in terms of yield occur.(Dechassa et al., 2003). Decrease in biomass of plants or the speed of growth under soils lacking phosphorus may be associated with either insufficient amount of absorbed photo-synthetically active radiation (PAR) or to a less effective transformation of the intercepted radiation (Plenet et al., 2000). P is vital to the transference of energy within planted crops. It pushes reactions and fuels growth. It also aids with root formation, growth of parts essential in reproduction and synthesis of proteins. Low soil P levels, impede all of these processes. External deficiency symptoms of P include red, withered and stunted leaves. The potential of sweet potato has continued to be essentially unexploited in Sub-Saharan Africa. Those doing farming under small scale produce an average yields that is ten times lower as compared those farmers that can easily access fertilizers, loans and water to irrigate who are the ones who produce for the purpose of earning income.(FAO, 2012). Sweet potato is mainly produced by female farmers in small farms and many people associate it with poverty. Production in Sub Saharan Africa is increasing at a high rate compared to that of other major crops and farmers are also able to select the best varieties. This positive production shift over the past decade is caused by factors such as crops such as cassava and bananas being seriously affected by diseases hence farmers opt for other crops such as sweet potato, increase in population leading to smaller farm sizes, unpredictable economy and the fact that farmers produce for purposes of selling to earn income (Joyce, 2022). With the tough climatic weather conditions and fatal viral disease, maize farmers are advised to accept to change to other crops produce. As opined by Kaguongo et al. (2012) the areas where sweet potatoes are grown in Kenya include the North Eastern, Coastal, and Western and Nyanza regions. In the Western region, Kakamega, Bungoma, and Busia are leading in the production of sweet potatoes, while in the Nyanza region, Homa Bay and Kisii counties are leading. In the year 2019 Kenya sold six tons of sweet potatoes to other countries. In the same year, the number of consumers of sweet potato tubers decreased by 77.7% compared to 2019. Between 2017 and 2019, sweet potatoes' sales to other countries went down by -85 percent earning Kenya US$0.01m for the year 2019 (FAO, 2019). Both local and improved varieties are grown. The varieties can be differentiated by their difference in skin and flesh color, shape of tubers and leaves, rooting depth, how long they take to mature, level of ability to resist diseases and other somatic characteristics. In Kenya, sweet potato is used as a primary meal and some families sell the crop to earn income. In rare cases, sweet potato is also used as an animal feed (Mukras et al., 2013). In terms of diet components, most individuals in rural and urban areas prefer sweet potatoes because is cheaper compared to other crops. Basing on nutrition, Vitamin A is abundant in sweet potatoes particularly in varieties whose flesh is yellow in color (Yanggen & Nagujia, 2005; Odendo & Ndolo, 2002). Sweet potato yields more calories and protein compared to Irish potato and maize (Nungo et al., 2007). Past efforts towards improving the root and tuber crops in Kenya have mostly focused on improving high-yielding varieties that are pests and disease tolerant (Government of Kenya [GoK], 2010). Embu West Sub County's main economic activity is agriculture, which is the economic pillar of Embu County, Kenya. Most of the people in the county depend on this sector for their livelihood, most of it being peasant (small-scale) farming. In fact, the Kenya

Agricultural Livestock Research Organization (KALRO) conducts research at the county's heart. Sweet potatoes are one of the main root and tuber crops grown by small-scale farmers within Embu West. Most farmers at the grassroots level have not been able to access proper fertilization on their farms because of a lack of adequate and authentic knowledge.

More research is vital to advance the quality and yield of sweet potato production. Although many studies have been done on sweet potato production in Embu West Sub County, little statistics exists on the effects of phosphorous application on sweet potato growth and yields. National Accelerated Input Access Programme [NAAIAP] - Kenya Agricultural Research Institute (KARI, 2014) reported that Embu West soils are deficient of P hence fertilizers rich in P need to be applied in order to prevent P level being a limiting factor in production. Does this deficiency affect sweet potato production and if so, what quantity of P should be applied to maximize sweet potato production?

1.2 PROBLEM STATEMENT

Deranged (use of excess or use of little) nutrient comparative to the government endorsements is a worldwide distress that brings about gaps in the quantity harvested from crops, with many examples in evolving and least-evolved countries that prove lost chances for bigger farm revenue and a hazard to ecologically viable agriculture because of dangerous off-site losses of nutrients (Dobermann et al., 2021). Excessive use of 1 or more nutrients brings about waste of nutrients and amplified hazard of environmental losses (Miao et al., 2011; & Recousetal, 2019).

cropping system pattern, season, fertilizer accessibility, financial position, preceding fertilizer usage, crop performance, soil quality, slope of land , guidance from fertilizer dealers and extension offers are among the factors that the farmer considers when making decisions on fertilizer use (Miah et al., 2019). In addition, the guidance of fellow farmers, profit viability of distinct crops, the including of principal food crops in the cropping system, inability to get soil testing services, and loyalty to conservative fertiliser practices are frequently reported obstacles to use of commended rates of fertilizer. (Baral et al., 2020; Miah et al., 2019; Ren et al., 2021). However, the communication between the rates that farmers use and those that the government recommends is hardly reported.

This study focused on the sweet potato fertilization regime, especially the application of phosphorous as it is the main root and tuber crop grown in Embu County. Phosphorus element is required by many plant species including sweet potatoes. It is essential for root development, blooming, and metabolic processes (Hameda et al., 2011). Most farmers apply phosphatic fertilizers, but the quantity that plants can access is not enough because it is transformed to an un-available form after reacting with constituents of the soil (Hassan et al., 2005). According to Hassan et al. (2005), application of P-fertilizers increases sweet potatoes production compared with the untreated control. Since P is a key element necessary for plant growth, including *Ipomea batatas* , the proposed research is aimed at comparing the levels of P and sweet potato yield and the interaction between the three varieties used and P levels.

There are persistent variations in yield and growth responses of sweet potatoes to fertilizer (N, P, and K) application. Nitrogen at very high levels promotes overabundances of vegetative growth suppressing formation of storing roots (Hartemink et al., 2000; Taranet et al., 2017). Some studies have indicated that sweet potato do not respond to phosphorus fertilizer application and agree that pre-existing levels of P in the soil are adequate. Several other studies have shown positive responses ofsweet potato to P fertilizer, but only at very high levels, varying between cultivars.

Sweet potato yields have been reported not to be significantly affected by the P level applied (Kareem, 2011). However, significant growth and yield responses have also been noted when more and more phosphorus was applied (Hameda et al., 2011). This is the gap this study tried to address. The gap is what exactly are the phosphorous requirements in sweet potato production? Is it even useful in the growing and developmental process of sweet potato? And if so, is it useful to the soils in Embu West Sub-County, and what levels should you apply to various varieties? All these questions and more were answered in this study.

1.3 GENERAL OBJECTIVE

The general objective of this study was to evaluate the effect of P application on the growth and yield of sweet potato varieties in Embu West sub-county.

1.4 SPECIFIC OBJECTIVES

i. To determine the yield of three sweet potato varieties.

ii. To determine the effect of phosphorus on the growth and yield of sweet potato varieties.

iii. To establish whether the interaction effect between P and variety significantly affects the growth and yield of sweet potato.

1.5 RESEARCH HYPOTHESIS

i. There is a significant yield difference in the three sweet potato varieties.

ii. The amount of P applied significantly affects the growth and yield of sweet potatoes.

iii. The interaction effect between P and variety significantly affects the growth and ` yield of sweet potato.

1.6 JUSTIFICATION OF THE STUDY

The Kenyan government has confirmed that sweet potato is among the crops guaranteed for guaranteeing dependable access to an adequate amount of inexpensive nourishing food. Most Kenyans depend on sweet potatoes as a source of food especially during famine. Therefore, all the efforts made are meant to improve food security by increasing the production of sweet potatoes. By improving production of sweet potatoes, food security which is becoming a perennial problem was be dealt with. Knowledge of the best varieties to use and the most economical fertilizer levels to use in sweet potato production in Embu west sub county, helped to provide a substitute for the diversification from the staple foods such as maize whose production has declined due to changes in climate leading to food insecurity.

Since sweet potatoes are said to be rich in many nutrients, consumption will improve the health of the consumers leading to healthy productive citizens. Increased growth and yield of sweet potatoes will improve the household income since excess tubers were sold to earn income while the vines will be fed to livestock whose production increased hence increasing the income from sale of their products.

CHAPTER TWO: LITERATURE REVIEW

2.1 PREAMBLE

This chapter analyses information under the following sub-themes: yield of different sweet potato varieties; the effect of phosphorous levels on the growth and yield of sweet potato varieties; the interaction effect between P levels and variety and how it significantly affects the growth and yield of sweet potato; and a summary of research gaps. This chapter also discusses the study's theoretical foundation. The chapter reviews literature from studies conducted from outside and within Kenya.

2.2 KENYA AND EMBU SOIL STATUS AND VARIETIES OF SWEET POTATOES GROWN

The difference in the parent material, average weather conditions and topography of the different areas in Kenya has resulted to a wide variety of soils. Soil properties differ in terms of soil type, fertility and depth. However, most of them have grave limitations such as salinity/ sodicity, acidity, fertility and drainage problems. Mzoba (2015) opined that although three quarters of the Kenyan people rely on Agriculture for food and revenue only about one third of the total acreage of land agriculturally useful, which includes the Kenyan highlands, coastal plains and the lake region. Most Kenyan Soils lack N, P and K. In dry parts, the soils have little organic matter majorly because of they receive little, inconstant, undependable and, unwell distributed rainfall.

County called Embu found in Kenya, which is located on southeast slopes of Mount Kenya, shelters the characteristic agro ecological summary of the area, from cold and wet high-altitude zones to the hot and dry low-altitude zones. According to a report by Ministry of

Agriculture Livestock and Fisheries (MoALF, 2016) Productivity in terms of agriculture in the County differs by agro ecological area subject to temperature and altitude. The county's agro ecological zones range from the cold and wet and cold areas that cover the windward side of Mt. Kenya represented by areas such as Manyatta and Runyejes to the Tana River Basin covering the Northern and southern side of Mbeere that are hot, dry and semi-Arid. The County is divided into eight agro ecological zones (GoK, 2013) which areLH1, which are cold and rainy and gets high quantities of rain (Runyenjes, Manyatta) and tea growing and dairy cows are kept. UM1, UM2 and UM3which experience warmth and humidity and maize, bananas, coffee and beans do well here. UM4, is represented by areas like Gachoka which have warmth and humidity where maize is grown here. LM3, LM4 and LM5 zones in Northern and southern parts of Mbeere are defined by high temperatures and dryness hence semi-arid; livestock that is tolerant to high temperatures are kept and drought-resistant crops are grown. The county produces both food and industrialized crops. Food crops include cowpea, sorghum and millet maize, bean, Irish potato, sweet potato, cassava, green gram while industrialized crops grown are coffee, tea, macadamia and cotton.

As postulated in NAAIAP-KARI (2014) In Embu West, the soil measure of acidity and alkalinity varies from from intensely acidic (4.6) to a little basic (6.1). Of the sixty farms tested, 28 percent of them have a pH of soil which is lower than 5.5. Many of them ninety five percent have their pH within the acceptable pH range (5-8) and therefore appropriate for the growing of sweet potatoes. It is essential for the farmers in this area to incorporate organic manure frequently to preserve and hold the organic material amount and rise the pH of the soil. Consequently incorporation of organic manure oftenly will also lessen aluminum toxicity in so doing increasing accessibility of P. The most limiting nutrients in Embu West soils are nitrogen, P and K with 88% of the 60 farms studied having P levels which are below sufficient hence fertilizers containing the three macronutrients should be applied before planting crops(NAAIAP-KARI, 2014) .

2.3 Yields of Different Sweet Potato Varieties

Ochieng (2019) carried out a study on sweet potato genotypes that grow in various environmental areas in Kenya under Morphological Characterization. The study was carried out in October 2013 and April 2014 in Miyare Agricultural Training College in Migori county and KALRO in Embu County. 68 genotypes, which were frequently grown by farmers in western, Nyanza and Eastern Regions of Kenya were used among them SPK004, Kenspot 3 and Kenspot 4.Randomized complete block design was used in planting the sweet potatoes with 3 replications. Above ground characters such as vine length, internode length, diameter of internode, and length of petiole were used. Underground characters such as length of storage root, diameter of largest root, root yield in Mt/ha were assessed. This study reported that effect of site and genotype significantly affected all agro morphological variables except length and diameter of vine internodes and weight of largest tubers.

Ribeiro et al. (2020) carried out a study on the plant growth, yield, absorption and removal of nitrogen by sweet potato crop onto which nitrogen fertilizer was applied and treated with PBZ during 2 growing periods. The results showed that when ,Paclobutrazol was applied it momentarily produced shorter main branches of sweet potato established in the season when it was raining but it did not decrease the shoot biomass of plants in both growing seasons. A rate of 50 kilograms of nitrogen per hectare during the wet periods, was adequate to achieve the highest harvest of fresh storage roots, but, in the dry spell, application of N enhanced the N uptake but did not increase root yield.

Akinjoba (2014) studied the result of P fertilizer on tuber yields, vegetative growth and uptake of P in sweet potato. A cultivar of sweet potato called Shaba was researched on for its aerial growth, quantity of produce and P uptake under the effect of 4 different fertilizers using randomised complete block design. The study was carried out in Ibadan University. Growth research reported that, SSP was the superlative amid them in terms of P release even though brought about reduced tubers yield. Those that were grown using crystallizer fertilizer at the rate of four forty five kilograms per hectare had the maximum P uptake and aerial growth while plots with no fertilizer produced plants with uppermost tubers yield. It is hence proposed that, crystallizer (445kg/ha) should be applied for noteworthy P uptake which at the same time leads to great tubers of *Ipomea batatas*, production and significant aerial growth. Maximum quantity of produce can also be attained when the amount of P in the soil is as little as 6.81 milligrams per kilogram of soil.

Dlamini et al. (2021) carried out a field investigation at the University of Eswatini, in Luyengo, in the course of twenty nineteen to twenty twenty cropping spell to find out how planting methods impacted the growth and yield of the three sweet potato cultivars. Two planting approaches, called horizontal and vertical; and 3 *Ipomea batatas* cultivars, namely Kenya-white, Ligwalagwala and Lamngititi were assessed in a Randomized complete block design which was repeated thrice. Outcomes indicated for the two cultivars, the two planting methods produced similar results for the growth and yield characteristics for they did not differ significantly in the three cultivars. Nonetheless, the upright planting method justly longer vines, more branches, higher weight and number of total tubers than the parallel method. (amongst the *Ipomea batatas* cultivars studied, most of the characteristics were significantly different ($P<0.05$)Among the three cultivars studied Lingwalagwala performed the best in terms of length of vines, total tubers per plant, weight of all tubers per plant and total tubers weight in tons per hectare. Recommendation was any of the studied planting methods and Ligwalagwala cultivar are useful in escalation the yield of *Ipomea batatas* in the research zone.

Mwololo et al. (2012) conducted a research to assess and recognize farmer-preferred adapted sweet potato varieties which are high yielding in terms of human food and animal feed. He carried out the study in 3 locations ie Mtwapa, Lukore and Mwaluvanga He used randomized complete block design (RCBD). The yield parameters used were marketable and non-marketable tubers, total tuber and vine. Yield parameters in both season and sites did not differ significantly. This research identified cultivars with traits that were most preferred by farmers and consumers and recommended distribution of sweet potato varieties that were able to withstand diseases together with building farmers ability to uphold clean vines can withstand sweet potato productivity.

2.4 EFFECTS OF PHOSPHOROUS LEVELS ON THE GROWTH AND YIELD OF SWEET POTATOES

Sufficient P nourishment boosts numerous traits of plant make-up, including the major photosynthetic route, nitrogen fixation, blossoming, bearing fruits seeding, and maturing. Roots growth, principally growth of side and fibrous roots is stimulated by Kareem (2011). In cereal crops, enough P nourishment reinforces structural tissues like the ones in straw or stalk, hence preventing lodging.

Crops planted in areas with insufficient phosphorus develop low total leaf area, which unpleasantly impacts on light capture therefore crops growth. The lower total leaf area could be because plants produce less leaves and which are smaller in size.

Hameda et al. (2011) undertook a study on the reaction of sweet potatoes to the combined influence of artificial and natural P fertilizer. They reported that increasing the P level from 25 to 100 kg P_2O_5 had a positive impact on weight of roots per plant, average fresh weight of roots, marketable and total tubers yield, while nonmarketable tubers harvest was reduced significantly compared to the control treatment. The unmarketable root yield differed insignificantly among the three phosphorus levels used. The highest increases for all tubers yield and its constituent qualities were obtained by applying the highest levels of phosphorus. This showed that phosphorus fertilizer application influenced sweet potato crop yields. They claimed that raising the amount of phosphorus applied from fifteen to forty five kg P_2O_5 ha^{-1} improved sweet potato root production and its constituents. Mineral fertilization may have enhanced both total and marketable sweet potato yields due to its beneficial impacts on vegetative development features, which raised fresh root weight, root weight $plant^{-1}$, and, as a result, root yield per field.

Kareem (2011) carried out a study on the effects of using different types and levels of phosphorus fertilizer on aerial growth, tubers yield and P uptake of *Ipomea batatas* in Nigeria. A cultivar of *Ipomea batatas* (Shaba) was resesrched on for its aerial growth, yield and P uptake under the impact of 4 fertilisers using randomized complete block design at the University of Ibadan. Development study showed that, SSP did the best amongst others in P discharge even though it brought about reduced tuber yield. In plots where crystallizer fertiliser at the level of four hundred and fourty five kilogrammes per hectare, highest P uptake was recorded and vegetative growth while experimental units without treatments produced crops with peak tuber yield. It is thus suggested that, crystalizer used at the level of four hundred and forty five kilograms per hectare to be used for noteworthy P absorption which eventually brings about improved quality *Ipomea batatas* root tubers yield and considerable aerial growth.

Yeng et al. (2012) carried out field experiments at Wa and Mampong-Ashanti in 2007 and 2008 to find out the how *Ipomea batatas* respond to fertilizer from chicken dung and artificial compound fertilizer (15-15-15), and their combination in terms of growth and yield. Using RCBD repeated four times, the treatments were1 sole NPK fertilizer, 1 sole chicken manure 2 different combinations of NPK and chicken manure and no fertilizer (control). A potato cultivar "Okumkom" was planted during the study period. Averagewise, all the combinations of treatments did better in terms of plant dry matter all through the period of growth than the sole or no fertilizer treatment at the two sites. Plant dry matter buildup formed at Mampong-Ashanti was greater than at Wa. The greatest amount of tubers that can be marketed were obtained from combinations at both locations This study recommended a combination of one hundred and fifty kilograms of the complete compound fertilizer per hectare plus one point five tons of fertilizer from chicken droppings for the study area and other areas which have similar conditions.

Kareem et al. (2020) determined the superior P fertilizer for enhancement of sweet potato P uptake, growth and yield. SSP, crystalizer and organic pacesetter were used as source of P while Shaba variety was used. The experiment was carried out using randomised complete block design (RCBD) repeated thrice. The highest uptake and growth was in plots where crystallizer fertiliser at the level of five hundred kilograms per hectare was applied whereas plots with no P applied gave crops with peak tuberous yield. It is, hence, suggested that crystallizer applied at the level of five hundred kilograms per hectare be used for noteworthy P absorption which similarly causes superior quality sweet potato tuber and significant asexual growth.

Kirui et al. (2018) carried out an experiment in Kericho County to assess the influence of Phosphate application on growing and productuctivity of four *Ipomea batatas* varieties. Those four sweet potato varieties were Kenspot 1 Kenspot 3, Kenspot 4 and Kenspot 5.The three phosphate levels used were 0 P_2O_5 kg/ha 30 P_2O_5 kg/ha and 60 P_2O_5 kg/ha. Randomized complete block design was used and was replicated thrice. Data on growth and yield parameters was collected and analysed. This study reported that variety had a non-significant effect on growth and yield. The level of phosphorus used meaningfully impacted the growing and production of sweet potato .The interaction between fertilizer treatment and sweet potato variety had a noteworthy impact on growing and production.

Balemi (2016) carried out a study in a meticulous growth compartment on the impact of phosphorus supply on morphological and physiological plant factors of 3 potato genotypes which had opposing phosphorus effectiveness. These genotypes include CGN 17903, CIP 384321.3 and CGN 18233. These were developed using 2 phosphorus rates one low and one high Using RCBD with 6 replications, Low P supply reduced most of the morphological and physiological plant parameters in the those genotypes that were not able to utilize P maximally, more than those that were able to maximally utilize phosphorus. Nevertheless, little phosphorus amount had no effect on net photosynthetic rate per unit leaf area, leaf dark respiration rate, chlorophyll fluorescence rate and electron transport rate of both P-efficient and inefficient genotypes. P-efficient genotype CGN 17903 dispensed extra dry matter to the leaf which could have aided greater light collecting, therefore causing great biomass buildup of this cultivar.

Idoko et al. (2017) carried out a study in 2014 and 2015 seasons in Makurdi in Benue State in Nigeria to gauge the influence of vine cutting size and inclination of planting on the growing and yielding performance of *Ipomea batatas*. 3 sizes of vines planting material (20, 30 and 40 centimeters) and 4 inclination levels of planting (45,90,180 and360 degrees of inclination) were used. For the two years, outcome indicated that entire growth parameters and yield parameters showed a significant increase ($P \leq 0.05$) with increase in length of vine cutting. This outcome also pointed out that root wideness, root size, number of commercial root, weight of commercial root and disposable yield ($P \leq 0.05$) decreased significantly with increase in inclination of planting, though unmarketable root number and noncommercial root weight showed a significant increase ($P \leq 0.05$) when planting inclination was increased.

Abdel-Razzak et al. (2013) undertook 2 field experiments in 2007 and 2008 summer spells to explain the growing, root amount and value reaction of *Ipomea batatas* to chemical and natural (P) fertilizer (superphosphate and rock phosphate) in 4 rates of phosphorus together with Vesicular Arbuscular Mycorrhiza (VAM) fungi inoculation treatment and their mutual effects. This report reported superior yields and quality with super phosphate compared to natural rock. Greatest rate of phosphorus (100% P_2O_5) boosted vine size, leaves amount and vine fresh weight and increased tuber amount and value characteristics. In general, the obtained results combining superphosphate at the endorsed rate and VAM fungi produced the highest quality and quantity of yield.

Dumbuya et al. (2016) carried out a study in Ghana on growth and yield response of *Ipomea batatas* to diverse fertilizer rates and cultivation approaches. The study was carried out in June to October 2014 using Randomized complete block design the treatments used were two tillage methods (mounds and ridges) and triple super phosphate fertilizer was used at 5 levels (0, 30, 60, 90 and 120 kg P_2O_5 / ha).Growth data was collected based on sum of foliage in every plant, sum of vine twigs in every plant, vine size and vine girth. Yield data was collected based on total number of roots in every plant, total number of commercial and noncommercial tubers per plant, weight of marketable and non marketable yield per hectare. Tillage methods had a non-significant effect on growth except on number of leaves per plant at 30 days. Similarly phosphorus application rates had a non-significant effect on growth of sweet potatoes. Both tillage methods and phosphorus level used had a significant effect on yield and its components. The yield components increased when the p levels were increase from 0kg P_2O_5 per hectare to 60 kg P_2O_5 kg per hectare but decreased when higher levels were applied as shown by 90 and 120kg P_2O_5 kg/ha.

Mkhatshwa et al. (2021) study intended at aiding agronomists with the precise vine size to be used for better growing and production of *Ipomea batatas*. The study was done at Luyengo college grounds, crop production farm throughout the 2019/2020 cropping season. Using Randomised Complete Block Design (RCBD) in a factorial organization with 3 repetitions. The treatments were vines with leaves, others without leaves and various lengths of both (25, 30, and 35 cm). Kenya white cultivar was used. Statistics was collected on growth and yield factors. Outcomes disclosed that vines without leaves gave significantly lower yields (P0≤.05) than those planted with leaves. This could be due to late action of photosynthesis in the earlier. The size of vine did not significantly impact on yield. The research resolved that vines for sweet potato propagation should have leaves and should be around 25 to 30 cm in size.

Chagonda et al. (2014) performed a research at Midlands State University in the 2013/14 raining spell, to define the influence of cultivation methods and vine placement direction on harvest of sweet potato. A two by three factorial treatment arrangement in a randomized complete block design (RCBD), repeated thrice was used. Two cultivation methods (ridging and mounding) and three vine alignments were practised (horizontal, fold and loop). Statistics about growth and yield parameters was collected and analyzed. The interaction between cultivation method and vine alignment had a non-significant effect on thickness of tuber, size of tuber and quantity of tubers. A significantly higher tuber diameter was noted with horizontal vine orientation. Equally the loop vine orientation produced a significantly lower tuber diameter. The loop and the horizontal vine orientations produced significantly high storage root yield. The fold vine alignment gave a significant the low (28.7 t/ha) tuber quantity. The study resolved that the horizontal and fold vine alignments produced the widest storing tuber thickness and the ridge had longer storage root sizes. The loop and horizontal vine alignments were commended in *Ipomea batatas* farming to achieve great amounts of produce.

Rashid and Waithaka (2022) researched on the influence of P fertilizer rates on the growth and tuber yield of 2 varieties of sweetpotato. There was no significant effect of P on growth and production in both varieties. Cv I (Musinya) produced considerably longer and a greater production of vines than Cv II (Gikanda), but then again Gikandi gave a considerably greater harvest and sum of storage roots than the Musinya. There was no significant effect of P on dry matter in both cultivars. Nevertheless, Cv I stored considerably greater amount of dry matter in the vines compared to Cv II, while Cv II accrued considerably greater quantity of dry matter in storage roots than cv. I in the course of the two growing periods.

Aarakit et al. (2021) studied the effect of P levels on development, quantity of product and p use efficiency (PUE) of potato cultivars developed from cuttings of the apex that had produced roots at Egerton University Njoro and Kenya Agricultural and Livestock Research organization, Molo, in a split plot organization using a randomized complete block design replicated 3 times. The treatments used were 4 sweet potato cultivars (Shangi, Dutch Robyjn, Unica and Wanjiku) and four P levels of TSP (0, thirty, sixty and ninety, kilograms of phosphorus per hectare). Statistics on development, quantity of tubers, and phosphorus use effectiveness of potato was recorded. P levels significantly affected plant development and quantity harvested. A combination of P rates and varieties significantly impacted plant survival, plant tallness, biomass of young branch, sum of eyes and tuber size. A combination of Wanjiku and thirty kilograms of phosphorus per hectare provided the uppermost sprout biomass of 0.42 grams in every plant and broader storage roots organ (> 60 mm diameter). Variety and P individually had a noteworthy influence on days to biological ripeness and salable tuberous produce. Unica cultivar exhibited great P absorption and phosphorus use efficiency in the two research areas. Cuttings from the apex which had been induced to produce roots and thirty kilograms of phosphorus per hectare is suggested in this region where the research was carried out and others when the environmental and soil conditions are the same.

Studies by Ngoroi et al. (2013) on sweet potato production in Embu County have looked at varieties for farmer preference. Farmers in Kithimu location in lower part of Embu County evaluated three varieties of sweet potatoes. Farmers gave taste as the most important criteria for sweet potato selection followed by texture and maturity period. This was followed by ease of cooking, root size, appearance and yield while skin color was of least importance. The recommendation given is that more work should be done using more farmer clusters spread across the target zone and consider more socio-economic issues like different gender in the adoption process. For sweet potato, work is needed to identify genotypes and select traits that can be manipulated to enable greater P uptake and/or lower the critical internal P concentration to produce maximum yield. The aim of this research was to define result of P levels on the growing, harvest and the level of ability of sweet potato to obtain P from the soil, in cultivars produced from Embu West sub-county of Embu, Kenya. Thus, the aim of this research was to evaluate the impact of P rates on the growing and quantity of sweet potatoes during planting seasons as stated in the second objective.

2.5 SUMMARY OF GAPS FROM LITERATURE REVIEWED

This study acknowledges that there are gaps in literature review on sweet potato production and technology use. One of the major gaps identified is that sweet potato variety improvement has been done without associated agronomic packages. The research wanted to fill this opening through studying the types of sweet potato varieties currently in use and the level of adoption by farmers. This study also sought to comprehend the absence of certified planting vines; tested the likelihood to proliferate the quantity of planting material using fertilizer to increase the vines production in the study area.

Few studies in Kenya have been documented on the influence of phosphorus application on growing and production of *Ipomea batatas* and hardly any in Embu West Sub County. This study will be conducted to fill the gap and assist famers of sweet potato to increase yield and save on using excess P fertilizer.

Many studies in Embu County have concentrated more on production of varieties resistant to sweet potato mottle virus and varieties for farmer's preference and not much has been documented on sweet potato fertilization. The research purposes to plug this gap by assessing the result of P application on sweet potato developmental process and quantity of harvest.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1: SUMMARY OF THE SITE

i) Location

The research was undertaken in KARLO, Embu that is positioned in Kangaru, Embu West Sub County, Central Division, Embu District in Embu County. Kangaru is 2km away from Embu town. It lies at an altitude of 1480m ASL.

ii) Climatology

The rainy season in Embu County is categorized into two weather conditions. Long heavy downpours usually happen from March through June, whereas the relatively brief rainfall eventuate from October all the way to December. The average amount of rainfall obtained a year is 1250 millimeters. Temperature varies from a minimum of $12^{o}C$ in July to $30^{o}C$ in March, a mean of $21^{o}C$. On the other hand, July has the coldest average monthly temperature of $15^{o}C$, whilst also September is denoted has one of the months with the warmest estimated weekly temperature of close to $27.1^{o}C$.

iii) Soils

Soil sampling was carried out at the location where experiment was done before conducting the research. Soil samples were sent to the research facility for evaluation to prove the nutrient composition as well as acid concentration of soils contents. Appendix 3 shows the soil analysis results. These results showed that the soil pH was 5.04(medium acid) which was satisfactory for potatoes growth. The levels of Nitrogen, potassium, calcium and magnesium were adequate but the level of phosphorus was low. The soil analysis report recommended that 2 tons/acre of well decomposed manure and 100kg/acre of SSP or TSP (45-51% P/Ha) be well worked out into the soil just before planting.

3.2 EXPERIMENTAL PROCEDURE

Land was cleared, dug and harrowed to fine tilt manually. Using RCBD, land was divided into three blocks. Each block had twelve plots each measuring three meters by three meters. There were three replications. Each plot received a combination of two treatments that is sweet potato variety and a specific level of P. Treatments was randomly assigned on the experimental units.

Sweet potatoes were propagated by use of vines which were sourced from KARLO Embu. The vines were planted in holes made on the prepared land. The phosphate fertilizer used was TSP which was in granular form. The granules were placed in the planting dumps and the carefully mixed with soil before placing the vine in the soil. Length of the vines planted was 30cm. 20cm of this was buried under the ground during planting. The vines were planted at a spacing of 100 × 50cm. Weeds, pests and diseases were controlled throughout the growing period. The plants were rain fed and no irrigation was done. Data on number of vine branches per plant and length of vines was collected at 30 days intervals from the day of planting up to 90 days and was used to determine the growth of sweet potatoes. Harvesting took place at the end of five months in each season. Data on total tubers yield, marketable tubers yield, and biomass above the ground, tuber diameter and length of tubers was collected at harvesting and used to determine the yield of sweet potato.

3.3: TREATMENTS AND TREATMENT COMBINATIONS

1) Treatments.

i) Sweet potato variety

Three sweet potato varieties were selected for use in the study.SPK004 was selected since it's a local variety and the farmers were conversant with it and many farmers in Embu West were already producing it. Kenspot 3 and Ken spot 4 were selected since they were new high yielding varieties that farmers in Embu county were encouraged to accept and grow in order to improve sweet potato yield.

(a) SPK 004- **V1**

(b) Kenspot 3- **V2**

(c) Kenspot 4- **V3**

(ii) P Levels

Four P levels were used in this study. Based on the recommendations from previous studies and soil analysis report which recommended 45-51kg/Ha 50kgP/Ha level was selected .An interval of 25 kg was used two come up with two more levels, one on the higher side of 50kg in order to find out the effect of applying excess P (75kg) and one on the lower side of 50kg in order to understand the effect of applying less P. The fourth P level was 0kg which would act as a control to study the growth and yield of the sweet potato varieties without P application.

Table 3.1

Levels of Phosphorus Fertilizer used

P(kg/ha)	TSP(kg/ha)	TSP(g/Plot)
0 (P1)	0	0
25 (P2)	123.5	111.15
50 (P3)	247	222.3
75 (P4)	370.5	333.45

2) Treatment combinations

Treatments were combined as shown in table 3.2

Table 3.2

Treatment Combinations

SWEET POTATO VARIETY	(PHOSPHORUS LEVELS) P1 (0kgP/ha)	P2 (25kgP/ha)	P3 (50kgP/ha)	P4 (75kgP/ha)
V1(SPK 004)	P1V1	P2V1	P3V1	P4V1
V2 (Kenspot 3)	P1V2	P2V2	P3V2	P4V2
V3 (Kenspot 4)	P1V3	P2V3	P3V3	P4V3

3.4: PLOT LAYOUT

Each plot measured 3m × 3m.The plots were arranged in blocks. Each block had twelve plots where a specific treatment consisting of a P level and variety was assigned randomly to each plot. There were three replications as shown in the layout below. There was a space between blocks measuring 2m as illustrated in the table 3.1.

Figure 3.1

Layout of the plot

BLOCK 1				BLOCK 2				BLOCK 3		
P1V2	P1V3	P1V1		P2V1	P2V3	P2V2		P4V2	P4V3	P4V1
P2V3	P2V1	P2V2		P3V3	P3V2	P3V1		P1V1	P1V3	P1V2
P3V2	P3V3	P3V1		P4V1	P4V3	P4V2		P2V3	P2V2	P2V1
P4V1	P4V3	P4V2		P1V2	P1V1	P1V3		P3V2	P3V1	P3V3

3.5 DATA COLLECTION

Data was collected during two seasons. The first season was during the long rains where planting was done 0n 16/4/2016 and harvesting was done five months later on 18/9/2016. The second season was during the short rains where planting was done on 2/11/2016 then harvesting was done five months later on 5/4/2017.Data on growth indicators (number of vines and vine length was collected at 30 days intervals up to 90 days after planting. Data on yield indicators (total and marketable tubers yield, above the ground biomass, length and diameter of tubers) was collected during harvesting from all the tagged crops.

Each plot had 4rows and each row had 7 plants. 2 inner rows from each plot were sampled, two plants from both the right and left end of each row were not sampled and the remaining 3 plants from each of the inner 2 rows were selected and tagged. Data on sweet potato growth and yield characteristics from each of the six tagged plants was collected and recorded as shown in table 3.3.

Table 3.3

Data collection

S/NO	Parameter.	Units.	How.	When.
1	Vine's length	Cm	Measuring using a tape	At 30, 60 and 90 days after planting
2	Vine branch per plant	Number/plot	Counting	At 30,60 and 90 days after planting
3	Total weight of tubers	t/ha	Weighing scale	At harvesting
4	Total weight of marketable tubers	t/ha	Weighing scale	At harvesting
5	Middle diameter of tubers	cm	Vernier calipers	At harvesting
6	Length of tubers	cm	tape measure	At harvesting
7	Biomass above the ground	t/ha	Weighing scale	At harvesting

3.6 Data Analysis

Data that was collected, was summarized using excel. ANOVA was done using SPSS version 23 at $\alpha=0.05$. LSD as Post hoc test was used to separate treatment means that were significantly different.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This section analyses as well as explains the main findings of the study of said field collected data. The data collected on sweet potato vine length and number of vines was used to show the growth aspect of sweet potato while that on total tubers yield, marketable tubers yield ,biomass above the ground, tuber length and tuber diameter showed the yield aspect of sweet potato. The discussion seeks to offer explanations of the results that are possible and to compare them with results that other researchers obtained in the past from similar studies. It is founded somewhat on research hypotheses, which were as follows:

i. There is a significant yield difference in the three sweet potato varieties.

ii. The amount of P applied significantly affects the yield and growth of sweet potato.

iii. The interaction between P levels and variety significantly affects the growth and yield potential of sweet potato.

4.1 Growth Parameters

Vine length and number of vine branches per plant were use as parameters to determine the effect of P application on growth of sweet potatoes. The results are as shown.

4.1.1 Vine Length

The longness **v**ine was measured on six labelled crops from each plot using a tape measure. All the branches were measured and the total was recorded. Data from vine length was used to compare the effect of P application on growth of sweet potato and to evaluate the effect of interaction between sweet potato variety and P level used on growth of sweet potatoes. ANOVA was used to determine whether the treatments seemed to have a significant influence on vine length, and the ANOVA summary is shown in table 4.1

Table 4.1

ANOVA Effect of Variety and P Levels on Vine Length

Source	Sum of Squares (Type III)	df	Mean Square	F	Sig.
BLOCK	24.044	2	12.022	0.089	0.915
VARIETY	7843.136	2	3921.568	28.975	.000
P level	38.482	3	12.827	0.095	0.963
VARIETY * P level	224.666	6	37.444	.227	0.999
Error	24361.896	180	135.344		
Total	351776349.6	215			

The length of the vines varied significantly among the three varieties of sweet potatoes ($p < 0.05$). LSD was used to isolate the means that displayed a significant difference, and the outcomes are demonstrated in table 4.2.

Table 4.2

LSD Effect of Variety on Vine Length

	SPK 004	KENSPOT 3	KENSPOT 4
SPK 004		-8.8201*	5.5394*
KENSPOT 3			14.6596*
KENSPOT 4			

* At the Level of 0.05, the mean difference is statistically significant.*

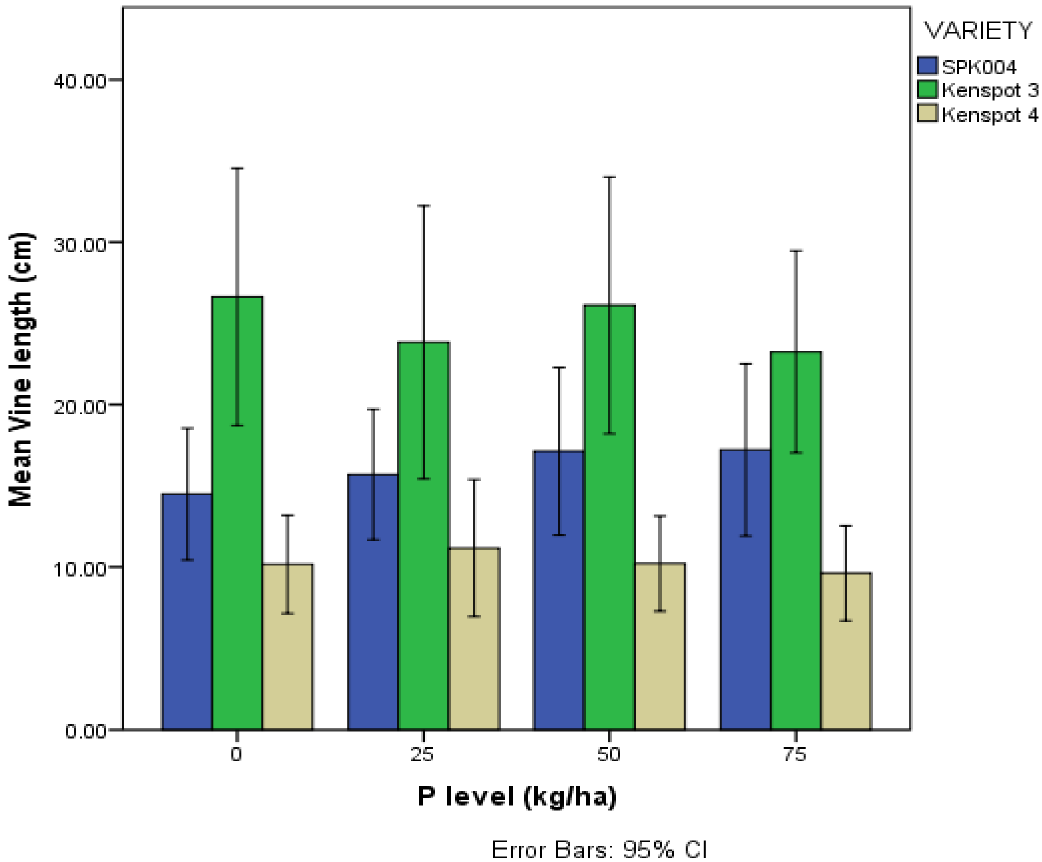
Kenspot 3 produced vines with a maximum length of 62.2cm, which were significantly longer than those of Kenspot 4(39cm) and SPK004 (48cm). SPK 004 produced vines which were significantly longer than Kenspot 4. The significant difference in the length of vines among the three varieties can be explained by the genetic variability among the sweet potato varieties. Ochieng(2019) reported that there was high level of genetic variability exhibited in sweet potato .This research also reported a significant difference in vine length between SPK 004, Kenspot 3 and Kenspot 4. Similarly Bonginkhosi et al. (2021) reported significant differences in vine length among sweet potato varieties which may be attributed to difference in genetic makeup in the varieties.

There was a no significant difference on vine length amongst the four P rates applied ($p > 0.05$) with P1, P2, P3 and P4 producing a maximum length of 56cm, 62cm, 61cm and 45.9cm respectively. This shows that no P level was superior to the other in terms of length of vines produced. The length of vines was discovered to also be none significantly affected by P levels according to this investigation. The above data are compatible from those of (Dumbuya et al., 2016) who ended up finding that P threshold seemed to have no significant effect on sweet potato vine length

Interaction between variety and P level did not significantly affect length of vines ($p>0.05$). The vine length for Kenspot 3 was highest with no P application (0kg /ha) and lowest with the highest level of P application (75 kg/ha). SPK 004 responded positively to P application as the vine length increased with increase in p level used. Kenspot 4 produced the lowest length of vines with the length highest at 50kg/ha of P levels as shown in figure 4.1.

Figure 4.1

The Effect of Varieties and P levels on Vine Length



. **4.1.2: The Number of Branches of Vines**

The sum total of vine branches from the six labelled plants in each experimental unit were counted during growing season, and the total number of vines per plot was recorded .This was used to asses he growth of sweet potatoes. ANOVA was used to see if the treatments seemed to have a substantial effect on the number of vines, as shown in table 4.3.

Table 4.3

ANOVA Effect of P Levels and Variety on Number of Vines

Source	Sum of Squares (Type III)	Df	Mean Square	F	Sig.
BLOCK	2673.787	2	1336.894	2.566	0.079
VARIETY	4668.593	2	2334.296	4.48	0.013
P level	4623.829	3	1541.276	2.958	0.034
VARIETY * P level	5350.963	6	891.827	1.711	0.12
Days after planting	135584.898	2	67792.449	130.098	0
Error	103696.699	199	521.089		
Total	259873.218	215			

The ANOVA summary revealed that the vine number differed significantly across the three sweet potato cultivars ($p < 0.05$). To separate the means LSD test was done and the outcomes are as shown in table 4.4.

Table 4.4

LSD Effect of Variety on Number of Vines

	SPK 004	Kenspot 3	Kenspot 4
SPK 004		9.94*	0.17
Kenspot 3			
Kenspot 4		9.78*	

. Only at level of 0.05, the mean difference is statistically significant

LSD results showed that SPK 004 gave considerably greater number of vines(218) than Kenspot 3(156). Kenspot 4 gave significantly greater number of vines(198) than Kenspot 3. SPK 004 produced a slightly higher number of vines than Kenspot 4 but the difference was not significant. This shows that Kenspot 4 and SPK 004 are more suited for production of propagation material since they produce more vines. According to Ochieng (2019), the variability mostly in number of vine strands among the varieties can always be thought to be due to genotypic differences.

Table 4.5

LSD Effect of P levels on Number of Vines

	0kg/ha	25kg/ha)	50kg/ha	75kg/ha
0kg/ha		-7.83	-8.02	2.35
25kg/ha			-0.19	10.19*
50kg/ha				10.37*
75kg/ha				

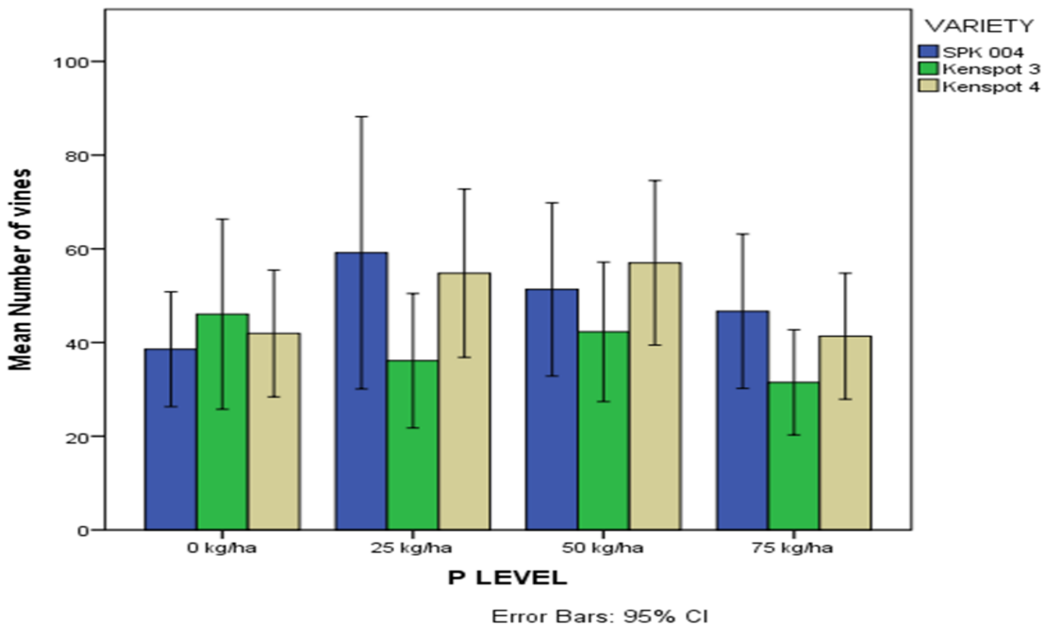
*. At the rate of 0.05, the mean difference is statistically significant.

Number of vine branches per plant differed significantly among the four P levels used .LSD results on effect of P level on number of vines showed that P level of 25 kg/ha produced significantly higher number of vines(218) than 75 kg/ha(103) .50 kg/ha level of Phosphorus produced significantly higher number of vines(153) compared to 75 kg/ha.50kg/ha produced slightly a non-significantly higher number of vines compared to 25 kg/ha (table 4.5) hence it would be more economical to use 25 kg/ha of phosphorus. The results show that application of high levels of phosphorus higher than 50 kg /ha reduces the number of vines produced by plants hence it's not economically viable. The findings of this research concurred to those of the (Hameda et al., 2011) who observed that attempting to increase the rate of P from about 15 to 45 kg P_2O_5/ha accelerated all development parameters of sweet potato crops. According to Hameda et al. (2011), crops made to give 45 kg P_2O_5/ha seemed to have big improvements throughout most vegetative and reproductive traits.

There was no effect of interaction between variety and P level on the number of vines produced per plant. This information is summarized in figure 4.2

Figure 4.2

Effect of P Levels and Variety on Number of Vines



4.2 Yield Parameters

The Parameters used as indicators of yield include total tubers yield, marketable tubers yield, above ground biomass tuber diameter and tuber length. Data collected from these parameters was used to effect of variety and P Level on yield of sweet potato.

4.2.1 Total Tuber Yield

Harvesting of sweet potatoes was done 135 days after planting. Tubers were extracted from six tagged plants in each plot. Tubers from each plant were weighed separately using a weighing balance, the total yield of the six plants was multiplied by 20,000 which is the plant population per hectare then divided by six to find out the total tuber yield per hectare. ANOVA results are as summarized in table 4.6

Table 4.6

ANOVA Effect of P Levels and Variety on Total Tubers productivity

Source	Sum of the squares (type iii)	df	Mean Square	F	Sig.
BLOCK	147.053	2	73.526	5.401	0.007
VARIETY	102.889	2	51.445	3.779	0.029
P LEVEL	121.073	3	40.358	2.964	0.04
VARIETY * P LEVEL	79.906	6	13.318	0.978	0.448
Error	776.028	57	13.615		
Total	1480.449	71			

ANOVA summary (table 4.6) reveals that the total yield of tubers differed significantly between the three sweet potato cultivars ($p<0.05$). LSD results are shown in table 4.7.

Table 4.7

LSD Effect of Variety on Total Tuber Yield

	SPK 004	Kenspot 3	Kenspot 4
SPK 004		0.79833	-2.04063
Kenspot 3			
Kenspot 4		2.8396*	

* Only at 0.05 level, the mean difference is statistically significant.

According to table 4.7, kenspot 4 gave considerably greater total tubers yields with a maximum quantity of 22.7tons than Kenspot 3 which produced a maximum of 21tons.kenspot 4 produced higher total tubers yields than SPK 004 (19.2tons) but the difference was not significant. SPK 004 produced higher total tubers yields than kenspot 3 but the difference was not significant. The significant yield disparities can always be attributed to the higher biological variation in Kenyan sweet potato genotypes, just like disclosed by researcher (Ochieng, 2019) who revealed substantial differences between genotypes above ground and below ground traits. The findings of this research independently confirm those from (Mwololo et al., 2012) who found a significant difference in total tuber weight among varieties.

Total tubers weight varied significantly among the P levels used. Separation of P level means results are as shown in table 4.8.

Table 4.8

LSD effect of P Levels on Total Tuber Yield

	0 kg/ha	25kg/ha	50 kg/ha	75 kg/ha
0 kg/ha		-1.2742	-3.35417*	-0.3922
25 kg/ha			-2.08	0.88194
50 kg/ha				2.96194*
75 kg/ha				

* Only at level 0.05, the mean difference is statistically significant.*

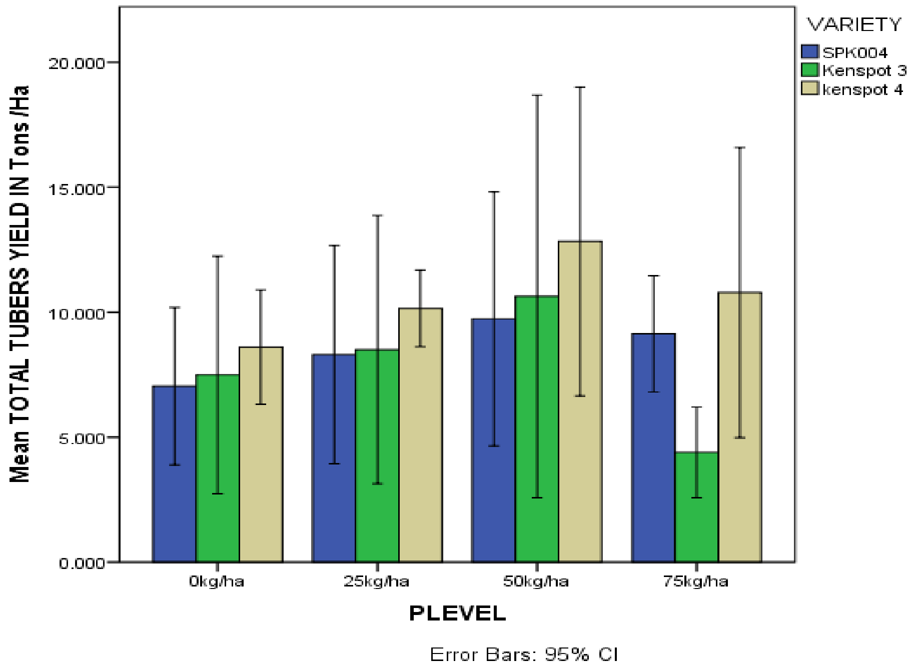
According to Table 4.8, applying 50kg P/ha produced a significantly higher yield (22.7 tons) than 0 kg/ha(13.5 tons). Application of 50 kg/ha of P also produced a significantly higher total weight of tubers than 75 kg/ha (18.2 tons). The usage of 50 kilograms of P per hectare resulted in higher agricultural output than that of the usage of 25 kilograms per hectare, but somehow the variance was still not considerable. This same production generated by 0 kilogram per hectare of P as well as 25 kilogram per hectare of P were not clearly distinguishable. This means that increasing P from zero to twenty five kilogram did not improve productivity substantially, but increasing it to 50 kg/ha did. Table 4.8 also shows that increasing the P level from 50 kg/ha to 75 kg/ha reduced total tuber weight, indicating that higher P levels should be avoided. The above findings are consistent from those of Hassan et al. (2005), who did find that P does indeed have a significant effect on the production. According to Dumbuya et al. (2016), output constituents improved from 0 kg/ha P_2O_5 to 60 kg P_2O_5

/ha, but decreased when levels above 60 kg P_2O_5 /ha were applied. According to Kareem et al. (2020) a decrease in total tuber yield could also be thought to be due to nutrient imbalance generated by extra added P via fertilization.

There was no significant interaction effect on total tubers yield. This means that no single variety did extremely different from the others when treated with a specific fertilizer level. These results are summarized in figure 4.3.

Figure 4.3

Effect of Variety and P Levels on Total Tuber Weight



All varieties produced the highest tuber yield at P level of 50 kg/ha. Total tuber yield increased with increase of amount of P applied but decreases at the highest level of P application (75 kg/ha). At 0 kg/ha of P application, kenspot 4 produced the highest total tuber yield.

4.2.2: Marketable Tubers Yield

After harvesting each of the tagged plants from each plot, marketable tubers (those with a middle diameter of more than 3cm and no longer than 30cm) were weighed using a weighing scale and their weight recorded. Weight from the six tagged plants from each plot was multiplied by 20000 which is the plant population per hectare then divided by six (the six sampled plants) to get the yield of marketable tubers per hectare. ANOVA results are shown in table 4.9

Table 4.9

ANOVA Effect of Variety and P Levels on Yield of Marketable Tubers

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BLOCK	118.788	2	59.394	4.659	0.075
VARIETY	94.746	2	47.373	3.716	0.03
P LEVEL	94.061	3	31.354	2.46	0.013
VARIETY * P LEVEL	89.572	6	14.929	1.171	0.335
Error	726.57	57	12.747		
Total	1330.931	71			

According to table 4.9, the yield of marketable tubers differed significantly among the three varieties used ($p<0.05$). LSD assessment was used to separate the variety are shown in table 4.10.

Table 4.10

LSD Effect of Variety on Marketable Tuber Yield

	SPK004	Kenspot 3	Kenspot 4
SPK 004		1.10697	-1.68321
Kenspot 3			-2.79013*
Kenspot 4			

The mean difference at level 0.05 is significant.

Table 4.10 shows that Kenspot 4(20.5tons) produced significantly higher marketable tubers yield than Kenspot 3 (18.1tons).Kenspot 4 produced higher marketable tubers yields than SPK 004(18.7 tons) but not significant. SPK 004 produced higher marketable tubers yields than Kenspot 3 but the difference was not significant. These results agree with those of (Kirui et al., 2018) and (Mwololo et al., 2012) whose results showed that yield of marketable and non-marketable tubers showed significant difference among cultivars

Yield of marketable tubers produced by the 4 different P levels applied differed significantly ($p < 0.05$).LSD assessment was used to separate the P level means and the results are as shown in table 4.11

Table 4.11

LSD Effect of P Levels on Yield of Marketable Tubers

	0 $kgha^{-1}$	25 $kgha^{-1}$	50 $kgha^{-1}$	75 $kgha^{-1}$
0 $kgha^{-1}$		-1.4137	-2.99411*	-0.47689
25 $kgha^{-1}$			-1.58039	0.93683
50 $kgha^{-1}$				2.51722*
75 $kgha^{-1}$				

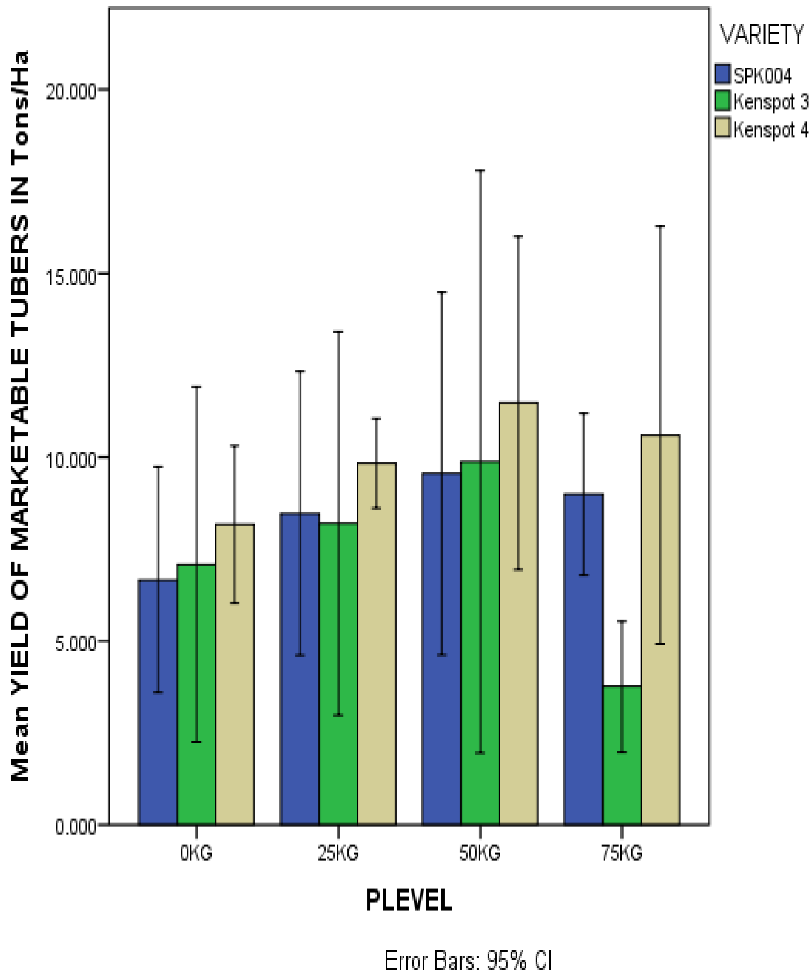
The mean difference at the level 0.05 is significant.

Table 4.11 shows that 50 kilogram of P per hectare applied produced significantly higher yields (20.5tons) than 0 kilogram P per hectare (13.4tons). Phosphorus at 50 kilogram per hectare produced a significantly higher yield than phosphorus at 75 kg/ha(17.5tons). Although the difference was not significant, 25 kilogram per hectare produced more yields(15.3tons) than 0 kilogram per hectare. Though the difference was not statistically significant, 50 kilogram/ha produced more yields than 25 kg/ha. Increasing the P level from 50kg to 75kg per ha resulted in a decrease in marketable tuber yield. These results tend to agree with (Dumbuya et al., 2016) that P fertilizer significantly affected the yield parameters on sweet potato. They reported that the low quantity of accessible native phosphorus in the soil may have contributed to the significant influence of P fertilizer on sweet potato yield components. This low quantity of native phosphorus was noted in the soils where this study was carried out as seen in appendix 3. The results are in conformity to those of the (Kirui et al., 2018) who ended up finding a significant effect of P fertilizer treatments on mean of both marketable and non-marketable tubers yields of sweet potatoes. The increase in marketable yield and yield components with steadily rising phosphorus application can sometimes be compounded by the fact that Phosphorus (P) is among the most essential minerals for several agricultural crops, which would include sweet potato (Hameda et al., 2011). P is very much an integral ingredient of very many organic compounds found in plants, which have been considered necessary for cellular metabolism, flowering, as well as root growth

On the yield of marketable tubers, there was no statistical significant interaction effect ($p>0.05$). Figure 4.4 summarizes the effect of P levels and variety on marketable tubers yield. According to figure 4.4, the marketable yield from each variety increased with increase in amount of P applied up to level of 50kg/ha. Kenspot 4 produced the highest yields at each level of P application while 50kg/ha produced the highest yields in each variety. Kenspot 3 produced the lowest yields at fertilizer level of 75kg/ha. At 0kg/ha, kenspot 4 produced the highest marketable weight of tubers hence can be the most appropriate variety to use for those farmers who do not want to apply fertilizers on their farm.

Figure 4.4

The Effect of P Levels and Variety on Marketable Tuber Yield



4.2.3 Above The Ground Biomass

During harvesting after 135 days, the biomass above the ground from six tagged plants per plot was cut from each plant using a sharp knife then weighed using a weighing scale. The weight from each of the six pants was added together, multiplied by 20000 which is the expected plant population per hectare when a spacing of 100 by 50 cm is used, then divided by six to get the yield of biomass above the ground per hectare. Above the ground biomass was used as an indicator of yield in sweet potatoes. To find out if the treatments had any significant effect on above the ground biomass, ANOVA was done and the ANOVA summary is as shown in table 4.12.

Table 4.12

ANOVA Effect of Variety and P Levels on Above the Ground Biomass

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BLOCK	30.062	2	15.031	1.915	0.157
VARIETY	71.836	2	35.918	4.577	0.014
PLEVEL	153.145	3	51.048	6.505	0.001
VARIETY * PLEVEL	30.921	6	5.154	0.657	0.685
Error	447.34	57	7.848		
Total	2812.162	71			

According to Table 4.12, there was a significant difference in above ground biomass among sweet potato varieties ($p<0.05$). This study's findings are in agreement with those of (Ochieng, 2019) who disclosed that consolidated ANOVA showed highly significant effect for varieties as well as sites throughout all quantitative characters ($p< 0. 05$). The findings of this research agree with that of (Mwololo et al., 2012) who discovered that vine fresh biomass showed significant difference among both seasons, sites, as well as varieties. The yield differences among the varieties could be thought to be due to different genetic makeup of the three varieties. The LSD test was also used to separate treatment means and thus the outcomes are included in tables 4.13

Table 4.13

LSD Effect of Variety on Above the Ground Biomass Yield

	SPK 004	Kenspot 3	Kenspot 4
SPK 004		-1.0025	-2.43387*
Kenspot 3			-1.43362
Kenspot 4			

The mean difference at 0.05 level is significant.

According to table 4.13, above the ground biomass yield obtained from Kenspot 4 was significantly higher with a mean of 12.8tons than that obtained from SPK 004 (8.4tons). Kenspot 4 also produced more above the ground biomass than Kenspot 3(11.39 tons) but the difference was not significant. Kenspot 3 produced a non-significant more yield than SPK 004.

There was a significant difference in above ground biomass among the four phosphorus levels used ($p<0.05$). The LSD test was also used to separate treatment means and thus the outcomes are included in tables 4.14.

Table 4.14

LSD Effect of P Levels on Above the Ground Biomass Yield.

	0 $kgha^{-1}$	25 $kgha^{-1}$	50 $kgha^{-1}$	75 $kgha^{-1}$
0 $kgha^{-1}$		-1.52561	-3.59883*	-3.333899*
25 $kgha^{-1}$			-2.07322*	-1.80828
50 $kgha^{-1}$				0.26494
75 $kgha^{-1}$				

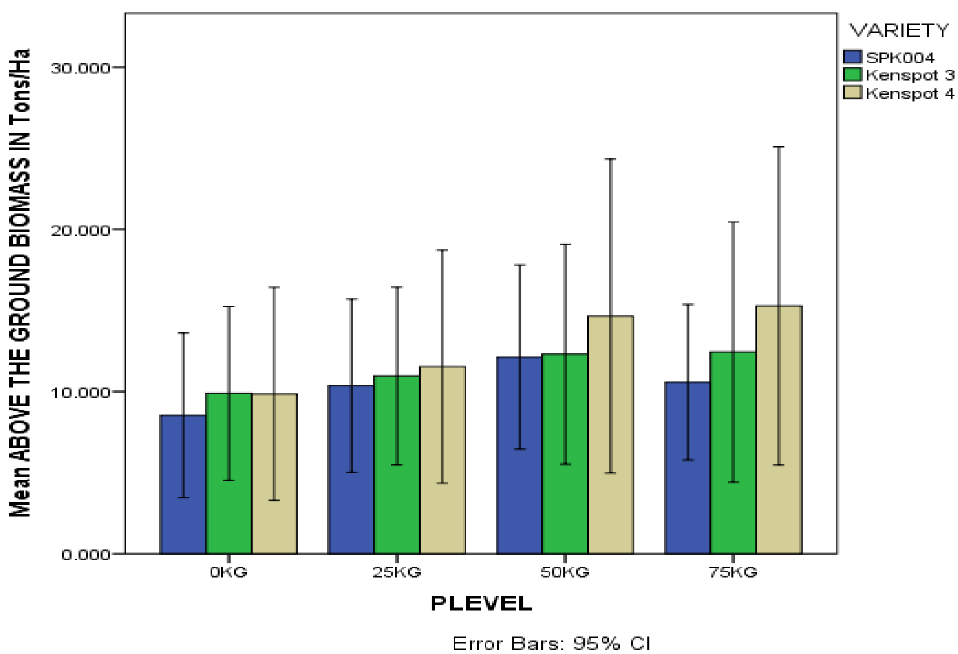
The mean difference is significant at the 0.05 level.

According to table 4.14, a P level of 50 kg/ha produced significantly higher Biomass above the ground yields (10.3tons) than 0 kg/ha (9.4tons). P level of 75 kg/ha also gave a significantly higher biomass above the ground (12.75tons) compared to 0 kg/ha. P level of 50 kg /ha produced a significantly higher biomass above the ground compared to a P level of 25 kg/ha (8.8tons). Although 50 $kgha^{-1}$ provided greater yield, the biomass rate of return recorded no statistical substantial difference from the range of between 75 $kgha^{-1}$ and 50 $kgha^{-1}$. The above results of the study are in agreement with the results of (Abdel -Razzak et al., 2013) who unearthed that increase of P rates boost both tuber and vine yield. It also increased the quality and quantity of root tubers showing that P as a nutrient is essential for high quantity production of sweet potato. This positive response to P could have been in response to poor soil P levels, which can be seen in Appendix 3.

There was really no significant interaction effect between variety and P level used on above the ground biomass ($p > 0.05$). The results obtained were as summarized in figure 4.5. Figure 4.5 shows that for each of the varieties used, the biomass above the ground increased as the P level was increased .Kenspot 4 produced more yield of biomass above the ground followed by SPK 004 and Kenspot 3. At 0 kg/ha P level (no fertilizer application), Kenspot 3 and Kenspot 4 produced almost similar biomass above the ground yield which was more than that from SPK 004 meaning that they can be used by farmers who want to grow dual purpose varieties with no P fertilizer at all. Since Kenspot 4 is also a high producer of marketable tubers, it can act as a dual purpose variety to be used even as feed for ruminants.

Figure 4.5

Effect of variety and P Levels on Above the Ground Biomass Yield



4.2.4: Tuber Diameter

After harvesting the tubers, the tuber diameter of each of the tubers harvested from the six tagged plants from each plot was measure using a Vernier calipers, and then the overall mean tuber diameter was calculated by dividing the sum total of all tuber diameters by the total number of tubers measured.

To find out if the treatments had any effect on tuber diameter ANOVA was carried out and the ANOVA summary is given in table 4.15.

Table 4.15

ANOVA Effect of Variety and P Level on Tuber Diameter

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BLOCK	10.262	2	5.131	14.665	0
VARIETY	7.061	2	3.53	10.09	0
PLEVEL	2.073	3	0.691	1.975	0.128
VARIETY * PLEVEL	1.995	6	0.332	0.95	0.467
Error	19.944	57	0.35		
Total	42.435	71			

Tuber diameter varied significantly between varieties ($p<0.05$). LSD was used to separate varieties, and the results are summarized in table 4.16.

Table 4.16

LSD Effect of Variety on Tuber Diameter

	SPK 004	KENSPOT 3	KENSPOT 4
SPK 004		0.76175*	0.30275
KENSPOT 3			-.45900*
KENSPOT 4			

The mean difference is significant at the 0.05 level.

Table 4.16 shows that the tuber diameter of SPK 004 (5.15cm) was significantly higher than that of Kenspot 3 (4.6cm).Kenspot 4 produced tubers with a significantly bigger diameter(5.0cm) than Kenspot 3. Although SPK 004 produced tubers with a larger diameter than Kenspot 4, their difference in tuber diameter was not significant. This means that SPK 004 and Kenspot 4 produced tubers with tuber diameter significantly bigger than Kenspot 3.The significant difference in tuber diameter among the varieties could be explained as due to genetic differences among the varieties. The results from this study agree with those of (Bonginkhosi et al., 2021) who reported a significant difference on the diameter of tubers between the sweet potato varieties. This may have been due to genetic differences among cultivars.

There was no statistically significant difference in tuber diameter across the P levels used. This may due to the reason that tuber diameter is due to effect of genetic makeup of the variety and other factors such as amount of soil water and the structure of soil.

The interaction effect between P levels and variety did not significantly affect tuber diameter of sweet potato. Figure 4.6 depicts a summary of this finding.

Figure 4.6

Effect of P Levels and Variety on Tuber Diameter

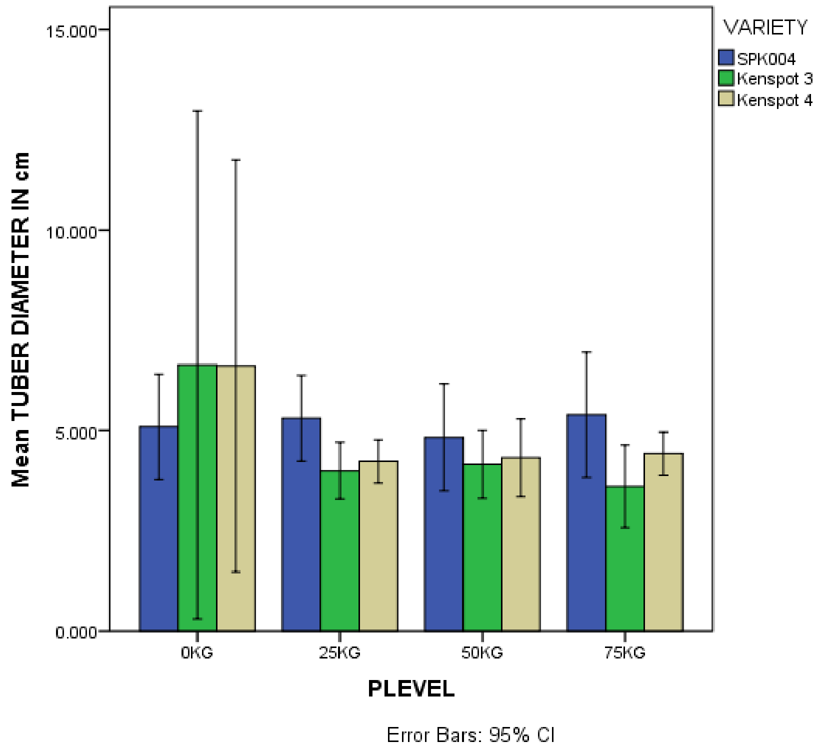


Figure 4.6 shows that the tuber diameter did not change with the level of phosphorus applied. There was a difference in tuber diameter among the varieties with SPK 004 producing tubers with the bigger diameter among the three varieties at all the 4 levels of phosphorus. The tuber diameter of kenspot 3 and Kenspot 4 was almost similar.

4.2.5 Tuber Length

After harvesting the tubers, the tuber length of each tuber harvested from the six tagged plants within every plot was measured with a measuring tape, and the mean tuber length was calculated by dividing the sum total of all tuber lengths by the total number of tubers measured. Tuber yield was used as an indicator of growth. To find out whether the treatments had any significant effect on length of tubers ANOVA was carried out and the statistical summary of the ANOVA is also presented in the Table 4.17.

Table 4.17

ANOVA Effect of Variety and P Level on Tuber Length

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
BLOCK	6.853	2	3.426	0.546	0.582
VARIETY	63.216	2	31.608	5.038	0.01
PLEVEL	18.374	3	6.125	0.976	0.41
VARIETY * PLEVEL	28.779	6	4.797	0.765	0.601
Error	357.606	57	6.274		
Total	576.755	71			

The mean difference is significant at the 0.05 level.

A statistical significant effect of variety on the length of tubers existed ($p<0.05$). . To separate the variety means, The LSD test was conducted, and the results are shown in table 4.18.

Table 4.18

LSD Effect of Variety on Length of Tubers

	SPK 004	Kenspot 3	Kenspot 4
SPK 004		1.5921*	2.2278*
Kenspot 3			0.6357
Kenspot 4			

The mean difference is significant at 0.05 level.

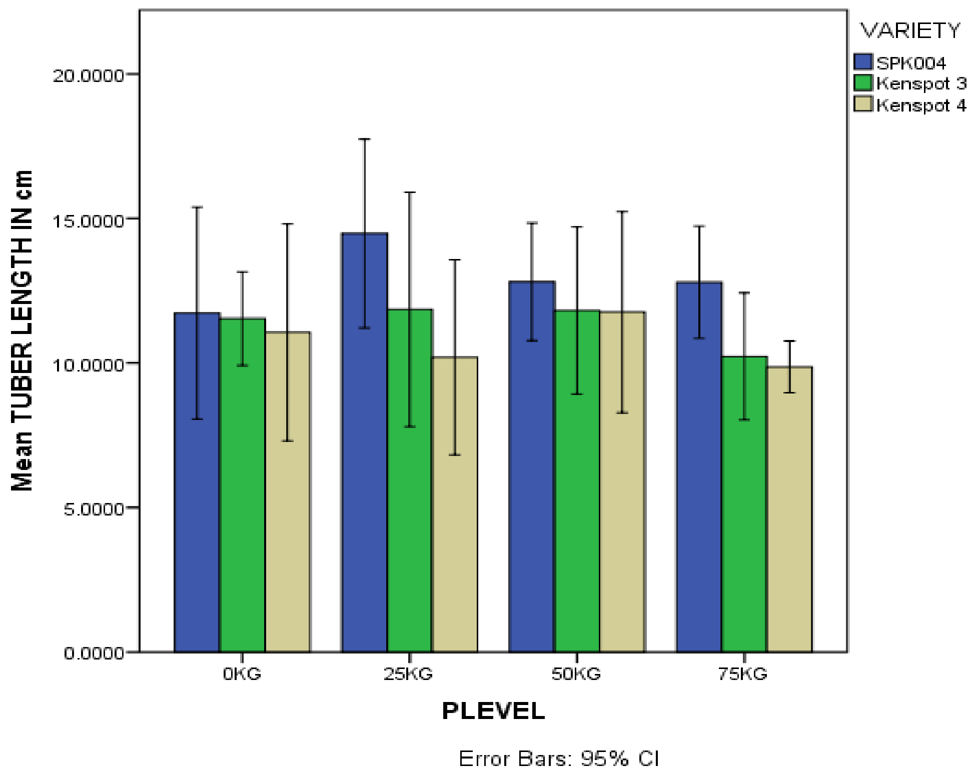
The table 4.18 above implies that SPK 004 produced significantly longer tubers(12.9cm) than `Kenspot 3(11cm) and Kenspot 4(9.7cm).Kenspot 3 produced a non-significant longer tubers than kenspot 4. The results from this study shows that SPK 004 had longest tuber length which differed significantly from Kenspot 3 and Kenspot 4.These results can be drawn from the differences in the genetic makeup of the said varieties since genetic and environmental factors influence plant growth and yield attributes.

Phosphorous level applied did not significantly affect the length of the tubers produced ($p>0.05$). This may be because tuber length as a morphological characteristic of sweet potato is determined more by the genetic makeup of the variety than by environmental factors hence there is no response of P application on length characteristics.

Table 4.17 also implies that no significant effect of interaction between variety and P level on length of tubers ($p>0.05$). Figure 4.7 depicts a presentation of this finding.

Figure 4.7

Effect of Variety and P on Tuber Length



According to figure 4.7, SPK 004 produced the longer tubers with Kenspot 3 and Kenspot 4 producing almost similar length of tubers. At all the P levels used, all varieties produced almost similar length of tubers.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSION AN RECOMENDATION

5.1: Introduction

Key objective of this study project was to theoretically and statistically assess the influence of phosphorus application on the growth and yield of sweet potato in Kenya using a case study of Embu west Sub County. This chapter therefore provides the conclusion of this study based on the objectives on the performance of the 3 sweet potato varieties that were studied, the 4 phosphorus levels used and the interaction effect between the phosphorus levels and the sweet potato varieties.

5.2: Summary

There were statistically significant difference in the yield from the three sweet potato varieties as indicated by yield parameters total tubers yield, marketable tubers yield, yield of biomass above the ground length of tubers and tuber diameter. The level of phosphorus applied had a significant effect on number of vine branches per plant. There was no significant impact of P level applied on length of vines. P level applied significantly affected the total and marketable tubers yield and the biomass above the ground. There was no significant effect of P level applied on the length and diameter of tubers. The interaction effect of variety and P level did not significantly affect any growth or yield parameter.

5.3 CONCLUSION

This research sought to determine the yield of three sweet potato cultivars. This study found that the sweet potato variety had a significant impact on growth and yield investigated parameters. There was a significant yield difference in the three sweet potato varieties. Kenspot 4 produced significantly higher total tuber yields than Kenspot 3. Kenspot 4 produced significantly higher marketable tubers yield than Kenspot 3. Above the ground biomass yield obtained from Kenspot 4 was significantly higher than that obtained from SPK 004. The tuber diameter of SPK 004 was significantly higher than that of Kenspot 3.Kenspot 4 produced tubers with a significantly bigger diameter than Kenspot 3. SPK004 produced significantly longer tubers than Kenspot 3 and Kenspot 4. In conclusion, Kenspot 4 produced the highest total yield of tubers, total marketable tubers yield, Biomass above the ground and significantly higher tuber diameter and this shows that it is the best among the three varieties and can be used as a dual purpose variety. Kenspot 4, also produced the highest total tuber yield at no fertilizer treatment (0kg/ha) hence it is appropriate for those farmers who cannot afford to buy fertilizers. SPK 004 produced tubers with the highest tuber diameter and the longest tubers hence more appealing to consumers who prefer long and wide tubers. SPK 004 and Kenspot 4 were also significantly better in growth parameters compared to Kenspot 3.

The objective of this study was also to determine the effect of four different phosphorus levels on the growth and yield of three different sweet potato varieties. In most parameters, the amount of phosphorus applied had a significant effect on sweet potato growth and yield. Although there was no significant effect of P level on length of vines, 75kgP/ha was found to produce lower length of vines for Kenspot 3 and Kenspot 4 but produced the highest length of vines for SPK004. On effect of P level on number of vines, P level of 25 kg/ha produced significantly higher number of vines than 75 kg/ha.50 kg/ha level of Phosphorus produced significantly higher number of vines compared to 75 kg/ha. Applying 50kg/ha produced a significantly higher yield than 0 kg/ha. Application of 50 kg/ha of P also produced a significantly higher total weight of tubers than 75 kg/ha. Similarly, no significant difference was recorded in total tuber yield between 0 kg/ha of P and 25 kg/ha of P This means that increasing the phosphorous level in a range between 0 to 25 kg did not necessarily increase the overall tuber production significantly, but increasing it to 50 kg/ha did. The study showed that increasing the P level further from 50 kg/ha to 75 kg per ha significantly reduced the total tuber yield hence higher levels of P should be avoided. 50 kg/ha of P applied produced significantly higher marketable tubers yields than 0 kg/ha.50 kg/ha phosphorus produced significantly higher marketable tubers yield than 75 kg/ha.25kg/ha produced higher marketable tubers yields than 0 kg/ha though the difference was not significant.50 kg/ha produced higher marketable tubers yields than 25 kg/ha though the difference was not significant. Increasing the p level from 50kg to 75kg per ha led to a decrease in yield of marketable tubers. P level of 50 kg/ha produced significantly higher Biomass above the ground yields than 0 kg/ha. P level of 75 kg/ha also gave a significantly higher biomass above the ground compared to 0 kg/ha. P level of 50 kg /ha produced a significantly higher biomass above the ground compared to a P level of 25 kg/ha. The amount of P applied did not have a significant effect on both the tuber length and tuber diameter. It can be concluded that a P level of 50kg/ha is the best for both growth and yield parameters.

Again, the study sought to establish whether the interaction effect between sweet potato varieties and phosphorus levels affected the growth and yield of sweet potato. The study found out that the interaction between variety and P levels did not significantly affect the growth and yield of sweet potatoes. On all the growth and yield parameters the interaction between variety and P level did not have any significant effect. This means that no specific combination of variety and P level stood out from all the others to be the best in terms of growth and yield.

5.4 Recommendations on Research Findings

Based on the results of this study, Kenspot 4 and SPK 004 are significantly better in growth and yield parameters compared to Kenspot 3 hence they are recommended for farmers in Embu west Sub County. Kenspot 4 is good in production of tubers and above the ground biomass hence it can be a good dual purpose variety. Kenspot 4 produced the highest yield without phosphorus hence it is also recommended for farmers who may not afford fertilizers. A P level of 50 kg/ha is recommended for farmers in Embu West Sub County since it produced significantly higher yields than the control and other P levels in all yield parameters. High phosphorus levels should be avoided since they tend to lower the growth as well as the yield parameters of sweet potato as demonstrated by P level of around 75kg/ha in this study.

5.5: Recommendations for Further Research

It is suggested that further research on interaction between sweet potato variety and season of planting and P level and season of planting should be carried out in order to understand why season significantly affected most growth and yield parameters. Research involving combining P with other primary macro nutrients that is nitrogen and potassium should be undertaken to find out whether they are a limiting factor. Since there was increase in yield as the P levels were increased a cost benefit analysis is recommended to ascertain exactly which level of P is economical for the farmers in order to maximize production with the minimum cost possible.

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APPENDICES

APPENDIX 1: EXCELL SUMMARY OF GROWTH AND YIELD DATA COLLECTED

a) Growth Data

SEASON	BLOCK	VARIETY	P level (kg/ha)	Days after planting	Number of vines	Vine length (cm)
1	1	V1	P1	30	12	9.4
1	1	V1	P2	30	21	11.8
1	1	V1	P3	30	34	8.8
1	1	V1	P4	30	15	10.7
1	1	V2	P1	30	18	9.1
1	1	V2	P2	30	16	9.1
1	1	V2	P3	30	30	12.2
1	1	V2	P4	30	17	10.3
1	1	V3	P1	30	17	10.1
1	1	V3	P2	30	27	5.8
1	1	V3	P3	30	25	4.56
1	1	V3	P4	30	18	6.8
1	1	V1	P1	60	28	17.2
1	1	V1	P2	60	63	24.5
1	1	V1	P3	60	66	25.9
1	1	V1	P4	60	39	18.6
1	1	V2	P1	60	49	21.8
1	1	V2	P2	60	42	24.2
1	1	V2	P3	60	63	32.6
1	1	V2	P4	60	53	38.9
1	1	V3	P1	60	24	10.7
1	1	V3	P2	60	50	10.9
1	1	V3	P3	60	52	10.6
1	1	V3	P4	60	55	10.2
1	1	V1	P1	90	76	6.3
1	1	V1	P2	90	195	7.9
1	1	V1	P3	90	153	9.1
1	1	V1	P4	90	89	8.1
1	1	V2	P1	90	119	23.2
1	1	V2	P2	90	118	22.6
1	1	V2	P3	90	124	23
1	1	V2	P4	90	102	20.5
1	1	V3	P1	90	76	3.4
1	1	V3	P2	90	143	3.8

1	1	V3	P3	90	120	3.7
1	1	V3	P4	90	90	3.6
1	2	V1	P1	30	19	10
1	2	V1	P2	30	23	11.5
1	2	V1	P3	30	13	13.7
1	2	V1	P4	30	14	14.1
1	2	V2	P1	30	16	9.1
1	2	V2	P2	30	10	10.15
1	2	V2	P3	30	15	8.3
1	2	V2	P4	30	13	8.6
1	2	V3	P1	30	15	3.7
1	2	V3	P2	30	23	5.2
1	2	V3	P3	30	23	6
1	2	V3	P4	30	7	5
1	2	V1	P1	60	46	19.1
1	2	V1	P2	60	67	23.5
1	2	V1	P3	60	36	17.7
1	2	V1	P4	60	53	25.6
1	2	V2	P1	60	82	32.6
1	2	V2	P2	60	17	14.4
1	2	V2	P3	60	39	24.7
1	2	V2	P4	60	16	13.9
1	2	V3	P1	60	20	22.4
1	2	V3	P2	60	36	14
1	2	V3	P3	60	50	14.29
1	2	V3	P4	60	18	15.7
1	2	V1	P1	90	85	38.1
1	2	V1	P2	90	218	25.2
1	2	V1	P3	90	75	29.2
1	2	V1	P4	90	98	35.5
1	2	V2	P1	90	156	56.6
1	2	V2	P2	90	31	28.4
1	2	V2	P3	90	51	61
1	2	V2	P4	90	39	28.1
1	2	V3	P1	90	37	12.1
1	2	V3	P2	90	57	14.3
1	2	V3	P3	90	126	15.7
1	2	V3	P4	90	33	12.8
1	3	V1	P1	30	15	8.1
1	3	V1	P2	30	18	7.1
1	3	V1	P3	30	21	6.6
1	3	V1	P4	30	15	7.9

1	3	V2	P1	30	8	13.3
1	3	V2	P2	30	11	11.5
1	3	V2	P3	30	23	7
1	3	V2	P4	30	13	10.5
1	3	V3	P1	30	19	4.2
1	3	V3	P2	30	18	4.3
1	3	V3	P3	30	14	3.3
1	3	V3	P4	30	10	5
1	3	V1	P1	60	39	17.3
1	3	V1	P2	60	51	18.8
1	3	V1	P3	60	51	18.5
1	3	V1	P4	60	41	16.6
1	3	V2	P1	60	29	19.8
1	3	V2	P2	60	18	14.2
1	3	V2	P3	60	54	26.9
1	3	V2	P4	60	18	14.5
1	3	V3	P1	60	36	9.2
1	3	V3	P2	60	41	8.4
1	3	V3	P3	60	19	8.3
1	3	V3	P4	60	20	8.4
1	3	V1	P1	90	63	10.9
1	3	V1	P2	90	75	14.48
1	3	V1	P3	90	96	21.8
1	3	V1	P4	90	97	22.2
1	3	V2	P1	90	60	47.2
1	3	V2	P2	90	45	35
1	3	V2	P3	90	88	50.3
1	3	V2	P4	90	38	31.5
1	3	V3	P1	90	67	16.2
1	3	V3	P2	90	114	39
1	3	V3	P3	90	60	15.6
1	3	V3	P4	90	20	13.1
2	1	V1	P1	30	13	9
2	1	V1	P2	30	12	8.5
2	1	V1	P3	30	15	8.6
2	1	V1	P4	30	11	11
2	1	V2	P1	30	9	7.7
2	1	V2	P2	30	10	7.6
2	1	V2	P3	30	16	6.4
2	1	V2	P4	30	16	7.6
2	1	V3	P1	30	18	4.3
2	1	V3	P2	30	23	6.4

2	1	V3	P3	30	29	5.3
2	1	V3	P4	30	31	5.2
2	1	V1	P1	60	33	15.4
2	1	V1	P2	60	25	12.48
2	1	V1	P3	60	40	12.1
2	1	V1	P4	60	47	12.9
2	1	V2	P1	60	25	24.8
2	1	V2	P2	60	24	22.6
2	1	V2	P3	60	28	33.3
2	1	V2	P4	60	28	32.9
2	1	V3	P1	60	58	10.3
2	1	V3	P2	60	64	10.1
2	1	V3	P3	60	80	15.1
2	1	V3	P4	60	61	10.4
2	1	V1	P1	90	49	29
2	1	V1	P2	90	53	38.9
2	1	V1	P3	90	70	48.3
2	1	V1	P4	90	69	45.9
2	1	V2	P1	90	46	48.8
2	1	V2	P2	90	35	62.2
2	1	V2	P3	90	19	28.1
2	1	V2	P4	90	41	42.8
2	1	V3	P1	90	63	23.3
2	1	V3	P2	90	74	22.4
2	1	V3	P3	90	76	27.1
2	1	V3	P4	90	80	28.7
2	2	V1	P1	30	11	7
2	2	V1	P2	30	17	8.8
2	2	V1	P3	30	12	9.79
2	2	V1	P4	30	10	6.6
2	2	V2	P1	30	11	12.2
2	2	V2	P2	30	35	6.1
2	2	V2	P3	30	11	12.45
2	2	V2	P4	30	13	11.2
2	2	V3	P1	30	13	4.5
2	2	V3	P2	30	18	5
2	2	V3	P3	30	14	5.6
2	2	V3	P4	30	28	4.5
2	2	V1	P1	60	27	12.8
2	2	V1	P2	60	34	14.6
2	2	V1	P3	60	30	14
2	2	V1	P4	60	13	11.7

2	2	V2	P1	60	33	41.9
2	2	V2	P2	60	35	41.6
2	2	V2	P3	60	26	27
2	2	V2	P4	60	36	41
2	2	V3	P1	60	44	8.65
2	2	V3	P2	60	37	9.1
2	2	V3	P3	60	80	10.9
2	2	V3	P4	60	58	10.7
2	2	V1	P1	90	42	9.3
2	2	V1	P2	90	68	12.7
2	2	V1	P3	90	52	14
2	2	V1	P4	90	43	11.3
2	2	V2	P1	90	62	17.2
2	2	V2	P2	90	35	16.3
2	2	V2	P3	90	44	25.4
2	2	V2	P4	90	55	25
2	2	V3	P1	90	54	6.6
2	2	V3	P2	90	70	8.1
2	2	V3	P3	90	103	10.43
2	2	V3	P4	90	87	8.3
2	3	V1	P1	30	14	10.4
2	3	V1	P2	30	14	10.4
2	3	V1	P3	30	14	10.2
2	3	V1	P4	30	19	7.9
2	3	V2	P1	30	9	12.1
2	3	V2	P2	30	16	9.9
2	3	V2	P3	30	14	8.6
2	3	V2	P4	30	9	11.2
2	3	V3	P1	30	20	5.9
2	3	V3	P2	30	20	6.4
2	3	V3	P3	30	31	7.2
2	3	V3	P4	30	19	5.7
2	3	V1	P1	60	38	12.3
2	3	V1	P2	60	28	13
2	3	V1	P3	60	47	12.3
2	3	V1	P4	60	64	15
2	3	V2	P1	60	25	35
2	3	V2	P2	60	61	34
2	3	V2	P3	60	41	32.8
2	3	V2	P4	60	25	34.5
2	3	V3	P1	60	62	11.2
2	3	V3	P2	60	67	11.1

2	3	V3	P3	60	58	8.6
2	3	V3	P4	60	43	7.4
2	3	V1	P1	90	84	19.2
2	3	V1	P2	90	83	18.4
2	3	V1	P3	90	99	27.7
2	3	V1	P4	90	103	28.3
2	3	V2	P1	90	72	46.9
2	3	V2	P2	90	91	59.1
2	3	V2	P3	90	75	49.9
2	3	V2	P4	90	35	35.4
2	3	V3	P1	90	112	16.3
2	3	V3	P2	90	104	16.8
2	3	V3	P3	90	66	11.48
2	3	V3	P4	90	66	11.7

b) Yield Data

S	B	V	PLVL	TOTAL TUBERS YIELD(t/ha)	MARKETABLE TUBERS YIELD(t/ha)	BIOMASS ABOVE THE GROUND (t/ha)	TUBER DIAMETER (CM)	TUBER LENGTH (CM)
1	1	V1	P1	9.86	9.46	8.98	5.2	14.82
1	1	V1	P2	15.83	15.36	16.13	4.652	16.27
1	1	V1	P3	19.2	18.77	17.32	5.03	15.896
1	1	V1	P4	12	11.76	15.4	5.515	14.75
1	1	V2	P1	13	12.4	16.5	3.9	14.375
1	1	V2	P2	15.33	14.33	17.83	4.785	12.318
1	1	V2	P3	21.8	20.56	21.8	5.648	15.851
1	1	V2	P4	6.68	5.3	25.21	5.475	14
1	1	V3	P1	7.86	7.2	17	4.503	8.615
1	1	V3	P2	11.27	10.933	17.5	5.05	16.65
1	1	V3	P3	22.76	18.13	20.39	4.227	12.436
1	1	V3	P4	18.2	17.53	22.44	4.984	11.4
1	2	V1	P1	10.81	10	15.73	5.263	16.842
1	2	V1	P2	9.6	9.4	15.383	5.79	15.68
1	2	V1	P3	10	9.82	16.383	3.33	11.559
1	2	V1	P4	11.58	11.15	13.8	4.357	13.762
1	2	V2	P1	3.8	2.9	14.3	2.15	10.11
1	2	V2	P2	3.76	3.6	15.03	2.818	6.5227
1	2	V2	P3	3.895	3.725	17	4.342	14.5526
1	2	V2	P4	4.28	3.92	16.4	3.318	10
1	2	V3	P1	7.93	7.63	12.5	3.13	18.103
1	2	V3	P2	10.1	10.03	14.45	3.93	9.55
1	2	V3	P3	16.05	13.8	26.61	5.03	14
1	2	V3	P4	8.62	8.57	27.5	3.75	9.786
1	3	V1	P1	8	7.766	12.75	4.136	11.591
1	3	V1	P2	8.16	8.1	13	4.572	18
1	3	V1	P3	8.53	8.1	17.23	4.856	14.375
1	3	V1	P4	7.33	7.16	11.87	5.062	12.423
1	3	V2	P1	13.5	13.36	12.08	4.693	10.361
1	3	V2	P2	14.5	14.5	13.55	4.025	11.946
1	3	V2	P3	18.7	18.2	14.3	4.01	10.35
1	3	V2	P4	2.72	2.28	13.45	3.744	10.389
1	3	V3	P1	12.6	11.96	16.47	3.708	10.804
1	3	V3	P2	12.3	11.16	20.59	4.141	9.591

1	3	V3	P3	5.7	5.26	21.5	5.522	16.37
1	3	V3	P4	4.16	3.96	20.49	4.59	9.227
2	1	V1	P1	5.33	5.3	4.62	4.82	9.933
2	1	V1	P2	5.5	5.4	7.08	5.375	10.25
2	1	V1	P3	6.22	6.15	6.12	5.08	12.583
2	1	V1	P4	8.43	8.43	12.6	5.87	13.375
2	1	V2	P1	3.83	3.45	4.88	4.545	10.909
2	1	V2	P2	4.3	3.86	5.36	4	10.786
2	1	V2	P3	4.3	3.375	5.6	3.313	8.688
2	1	V2	P4	5.65	5.05	4.91	3.389	9.44
2	1	V3	P1	8.5	7.7	4.28	4.788	8.818
2	1	V3	P2	9.15	8.88	5.56	4.581	9
2	1	V3	P3	10.9	10.73	6.1	4.9	8.969
2	1	V3	P4	16.63	16.63	8.93	4.656	10.219
2	2	V1	P1	3.1	2.37	4.18	3.455	7.545
2	2	V1	P2	4.105	6.03	4.315	3.709	15.68
2	2	V1	P3	6.4	6.4	8.85	4	11.5
2	2	V1	P4	8.9	8.9	4.95	3.571	9.357
2	2	V2	P1	4.97	4.87	7.16	3.5	11.611
2	2	V2	P2	6.14	6	8.233	3.882	11.0588
2	2	V2	P3	7.34	5.93	8.63	3.76	10.76
2	2	V2	P4	4.9	4.9	8.53	3.055	9.944
2	2	V3	P1	6	6	2.98	3.64	10.818
2	2	V3	P2	8.21	8.16	5.08	4.103	8.034
2	2	V3	P3	11.55	11.5	7.51	4.381	11.571
2	2	V3	P4	10.2	9.98	7.01	3.828	9.448
2	3	V1	P1	5.16	5.1	4.92	4.308	9.615
2	3	V1	P2	6.62	6.5	6.25	3.667	11
2	3	V1	P3	8.08	8.08	6.816	4.688	10.938
2	3	V1	P4	6.56	6.56	4.8	5.4	13.11
2	3	V2	P1	5.86	5.5	4.42	3.048	11.857
2	3	V2	P2	7	6.9	5.77	4.5	18.5
2	3	V2	P3	7.76	7.46	6.47	3.857	10.714
2	3	V2	P4	2.13	1.13	6.07	3.667	7.6
2	3	V3	P1	8.73	8.56	5.9	3.588	9.233
2	3	V3	P2	9.9	9.83	6	4.16	8.382
2	3	V3	P3	10.03	9.43	5.8	4.5	7.238
2	3	V3	P4	6.93	6.9	5.3	4.75	9.125

APPENDIX 2: Meteorological Report of Weather during the Two Research Seasons

AVERAGE MONTHLY RAINFALL, MINIMUM TEMPERATURE AND RH IN 2016 AND 2017

	2016			**2017**		
	RAINFALL	TEMP	RH	RAINFALL	TEMP	RH
JANUARY	1.4	14.4	72.7	0	12.4	56.8
FEBRUARY	0.3	14.4	61.1	1.4	14.1	69.6
MARCH	1.7	15.9	70.2	1.1	15.1	66.8
APRIL	12.4	15.6	79.2	5	15.6	79.8
MAY	4.9	15.7	84.5	8.1	15.9	79.9
JUNE	2.3	14.3	82.7	0.2	15	78.3
JULY	0.2	13.1	81.5	0.6	13.6	80.9
AUGUST	1.2	13	79.6	0.6	14.1	79.4
SEPTEMBER	1	13.4	82.6	1.4	13.7	75.2
OCTOMBER	0.8	14.3	72.7	7.3	14	70.5
NOVEMBER	7.5	15.3	83.3			
DECEMBER	0.5	13.6	69.2			

APPENDIX III: SOIL ANALYSIS REPORT

Kenya Agricultural & Livestock Research Organization

National Agricultural Research Laboratories

P. O. Box 14733, 00800 NAIROBI

Tel: 0202464435

Email: soilabs@yahoo.co.uk

SOIL TEST REPORT

Name	Tabitha MUGAI
Address	P. O. Box 58, Chuka
Location of farm	KALRO, Embu
Crop(s) to be grown	Sweet potato
Date sample received	30-03-16
Date sample reported	14-04-16

Reporting officer (through Director NARL) A. Chek

	Soil Analytical Data							
Lab. No/2017	952							
Soil depth cm	top							
Fertility results	value	class	value	class	value	class	value	class
* Soil pH	5.04	medium acid						
Exch. Acidity me%	0.3	adequate						
* Total Nitrogen %	0.21	adequate						
* Total Org. Carbon %	2.26	moderate						
Phosphorus ppm	10	low						
Potassium me%	0.86	adequate						
Calcium me%	4.8	adequate						
Magnesium me%	2.13	adequate						
Manganese me%	1.11	adequate						
Copper ppm	4.20	adequate						
Iron ppm	24.8	adequate						

Zinc ppm	22.4	adequate							
Sodium me%	0.57	adequate							

*** ISO/IEC 17025 accredited**

Interpretation and Fertilizer Recommendation

The soil reaction (pH) is satisfactory for potatoes' growth. Phosphorus is deficient. Soil organic matter content should be improved. **Sweet potato:** Sweet potato plant prefers soils in acidic to neutral range (pH 4.5 - 7.5) with an optimum pH of 5.5 - 6.6. The soil must be fertile and well drained. Just before planting apply 2 tons/acre of well decomposed manure or compost and 100 kg/acre of single superphosphate (SSP) or triple superphosphate (TSP). The manure and fertilizer should be well worked into the soil.

NOTE: Test results are based on customer sampled sample(s).