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Effects of potassium fertilizer rates on growth, tuber yield and quality of sweet potato (*Ipomea batatas* L) in Ogbomoso, Southwest Nigeria

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Abstract

Sweet potato (Ipomoea batatas L) is an important dicotyledonous tuberous staple crop of the Convolvulaceae family. It is valued for its tubers which are either boiled, fried, baked or roasted for human consumption or boiled and fed to livestock as a source of energy. However, the cultivation of sweet potato is constrained by low soil fertility, particularly inadequate potassium, which plays a pivotal role in the growth and tuber development of sweet potato. Therefore, the effects of potassium fertilizer rates on the growth, tuber yield and quality of sweet potato were determined at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso during 2022 major cropping season. The treatments were; 0 (control), 60, 90, 120, 150 and 180 kg K_2O/ha laid out in randomized complete block design replicated three times. Data collected on length of primary vines, number of leaves, fresh shoot biomass, number of tubers, fresh tuber yield and nutritional contents of the tubers were subjected to analysis of variance and treatment means separated with least significance difference (LSD) at 5% probability level. The application of K fertilizer had significant influence on the performance of sweet potato. At 14 weeks after planting (WAP), plants treated with 180 kg K_2O/ha produced the longest mean vine length ($p = 0.043$, 184.93 cm), highest number of leaves ($p = 0.003$, 217), highest fresh shoot biomass ($p = 0.015$, 11.83 t/ha), number of tubers ($p = 0.037$, 68) and fresh tuber yield ($p = 0.0004$, 22 t/ha). In contrast, plants that received no fertilizer, had the shortest vine length (133.67 cm), the least fresh shoot biomass (7.1 t/ha) and tuber yield (12.7 t/ha). The least number of leaves (136) was observed with the application of 60 kg K_2O/ha while 90 kg K_2O/ha produced the least number of tubers (46). The potassium content of sweet potato tuber was significantly influenced by K fertilizer rates, whereas the phosphorus content was unaffected. The highest contents of phosphorus ($p = 0.967$, 0.10%) and potassium ($p = 0.038$, 1.26%) were recorded in tubers that received 150 kg K_2O/ha and 180 kg K_2O/ha, respectively. The carotenoid, carbohydrate, and protein contents of sweet potato tuber decreased as the potassium rates increased. Conversely, the crude fiber content increased ($p = 0.044$) as the potassium rate increased. In conclusion, application of 180 kg K_2O/ha improved the performance of sweet potato better than the other rates in the study area. However, it seems that the maximum yield potential of sweet potato in the study area had not been attained. Therefore, further research with higher than 180 kg K_2O/ha may be required to identify the optimal level for cultivating sweet potatoes.

***Keywords**: Sweet potato, potassium fertilizer, Application:*

Introduction

Sweet potato (*Ipomoea batatas* L.) is a dicotyledonous tuberous plant of the Convolvulaceae family. Out of the 45 genera and 100 species in the family Convolvulaceae, only *Ipomoea batatas* are of economic importance as food (Owolabi *et al.,* 2020). It is an important staple crop

(Gichuru*et al.,* 2022); it thrives in the tropical, subtropical and temperate regions of the developing world (Alam *et al*., 2016). Sweet potato has numerous potential benefits and uses. This crop thrives in challenging environments like drought and poor soil. It requires fewer inputs and less labour than other crops like cereals, yet boasts superior of productivity (Mwanga *et al*., 2022). Sweet potato is an important food and feed crop in sub-Sahara Africa (SSA) and ranks fourth after maize, bananas, and cassava (FAO, 2022). The potential of sweet potato as a guarantee for food security is underestimated, as it is often limited to a substitute food in African countries. The sweet potato is esteemed for its roots, which can be prepared by boiling, frying, baking, or roasting for human consumption. Additionally, the tubers can be boiled and provided to livestock as a means of supplying energy. The tubers can also be processed into flour for bread making, starch for production of noodles as well as used as raw material for industrial starch and alcohol (Ukom *et al*., 2017; Oboh *et al*., 2023). Besides its use in sweetening local beverages like Kunu-zaki and burukutu, the flour also plays a role in fortifying baby foods, fufu and pounded yam in Nigeria (Tewe *et al*., 2015; Olatunji *et al.,* 2021). The foliage serves as a vegetable component in yam and cocoyam porridge, providing abundant proteins, vitamins, and assorted minerals. Furthermore, the leaves are used as food product and food ingredient for cattle, pigs, and chicken (Abdulrazea, 2014; Adugna *et al.,* 2020). In Nigeria, sweet potato is prepared into potato chips. More so, the starch from sweet potato is widely used by pharmaceutical, textile, wood and paper industries as adhesive agent (Ibitoye, 2022). Sweet potato tubers are rich in vitamins A, B and C; and minerals such as K, Na, Cl, P and Ca (Ahmed *et al*., 2020). It can therefore be a high value added food particularly for children and pregnant women who are more often exposed to deficiency of Vitamin A in sub-Saharan Africa (Degras, 2013; Muthayya *et al.,* 2020). Tadesse *et al.,* (2022) confirmed that yields of sweet potato is presently restricted by many factors among which are low soil fertility, the varietal selection, planting date, weather condition, variations in soil composition, the presence of weeds, insect and disease challenges, and agricultural management techniques are among the factors to be considered. The plant flourishes in less fertile soils; however, enhanced soil fertility boosts its growth and overall yield.

In the past, soil fertility was maintained through long fallow periods, but presently, due to population pressure as well as urbanization and industrialization, fallow periods have been reduced from 10 years to 1-2 years, resulting in declining crop yield (Akinde *et al.,* 2020). Among the various management practices, fertilizer application stands out as a critical strategy for farmers to enhance sweet potato yields in most soil types. In this context, potassium fertilization plays a vital role in promoting tuber growth and maximizing production (Hahn, 2015). However, sweet potato, like other root and tuber crops, is a heavy feeder, utilizing a substantial amount of soil nutrients and water (Osundare, 2014). In Nigeria, low soil fertility stands out as a significant constraint in sweet potato production (Okpara, 2018). Consequently, these soils necessitate supplementation with ample macronutrients to sustain productivity (Aisha *et al.,* 2017). Hence, external nutrient inputs are imperative to enhance and sustain the growth and yield of sweet potatoes, which may originate from either organic sources or inorganic fertilizers (Adekiya *et al.,* 2017). The objective of this study was to determine the effects of K fertilizer rates on the performance of sweet potato (*Ipomoea batatas* L).

Materials and Methods

Experimental Site

The study was conducted at the Teaching and Research Farm, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Oyo State, Nigeria, during the 2022 major raining season. Ogbomoso is located in the derived savanna agroecological zone at latitude $8^0$10′N and longitude $4^0$10′ E.

Land preparation and plot layout

The land was cleared of bushes using cutlass; ploughed twice using tractor mounted mound board plough and ridged using hoes. Ridges were spaced 0.75 m apart on each plot. The total experimental area was 391 m^2. Plots were arranged in three (3) replicates, with six (6) plots per replicate, making a total of eighteen (18) plots. Each plot was 15 m^2 (3 x 5 m). There was space of 1 m each between plots and replicates.

Soil sampling and analysis

Soil samples (0 – 15 cm depth) were taken randomly with soil auger before planting. Composite soil sample was air – dried, crushed using ceramic mortar and pestle to pass through 2 mm and 0.5 mm sieves to remove unwanted materials like stones, plants remains and debris. A sub sample was taken to the laboratory for analysis of N, P, K, Ca, Mg, organic C, available P, exchangeable bases and particle size distribution. Organic matter content was determined using the Walkley-Black test (1934). Total nitrogen was determined using the Kjeldahl method (Kjeldahl, 1883), the Bray 1 method for available phosphorus (Bray and Kurtz, 1945), and the extractable ammonium acetate NH_4O_{AC} method for potassium (Pratt, 1965). Calcium and magnesium were measured using the atomic absorption spectrophotometric method (Chapman and Pratt, 1961) and the EDTA complexometric titration method (Lindsay and Norvell, 1978), respectively. Particle size distribution was determined through the hydrometer method (Gee and Bauder, 1986).

Treatments and experimental design

There were six (6) treatments laid out as randomized complete block design (RBCD) replicated three (3) times. The treatments were as follows: T1: Control (No fertilizer), T2: 60 kg K_2O/ha, T3: 90 kg K_2O/ha, T4: 120 kg K_2O/ha, T5: 150 kg K_2O/ha., T6: 180 kg K_2O/ha.

Agronomic activities and fertilizer application

Cream fleshed sweet potato (CFSP) vines were obtained locally from Ikose town, Orire Local Government Area, Oyo State. Five node cuttings of the vines were planted on the ridge at a spacing of 75 cm inter row and 50 cm intra row (equivalent to 55 plants/plot or 26,666 plants per hectare). The fertilizers used included Muriate of Potash (MOP) for potassium (K), single superphosphate (SSP) for phosphorus (P), and urea for nitrogen (N). Nitrogen (urea) and phosphorus (SSP) were applied at 30 and 15 kg/ha respectively to all plots at planting. Weeds were controlled biweekly using hoes and rouging.

Data Collection

Five sweet potato plants were randomly selected per plot and tagged for data collection from six weeks after planting and at two weeks interval until the crops mature.

Length of primary vine**:** A measuring tape was employed to measure the length from the ground level to the uppermost leaf.

Number of leaves**:** The number of fully opened leaves was visually counted for each.

Fresh shoot biomass**:** At 14 weeks after planting, the weight of fresh biomass in the net plot measuring 1.5 x 4 m (27 plants/plot) was measured on weighing scale using a Camry platform digital led scale.

Harvesting

Sweet potato tubers were harvested 106 days after planting. The soil around the base of the sweet potato was carefully loosened, and the tubers were packed separately for each treatment within each plot. The number of tubers within the net plot of 1.5 x 4 m was determined by counting and the weight of the tubers was measured using a weighing scale.

Nutritional Analysis

Five sweet potato tubers samples per plot were washed and peeled carefully using stainless steel knives and sliced. The slices were dried in a hot air oven at 65^0C for 72 hours. Afterward, the samples were finely ground into powder using a mortar and pestle and then stored in polyethylene plastic bags for analysis. The nutritional content, including carbohydrate, crude fibre, carotenoids and protein, as well as elemental contents; phosphorus and potassium were determined following the methodology outlined by the Association of Official Analytical Chemists (AOAC, 2012).

Statistical analysis

The data were subjected to Analysis of Variance (ANOVA) procedure using SAS and the treatments means were separated using least significance difference (LSD) at 5% probability level.

Results

Pre planting Soil properties

The soil had low levels of organic carbon, total nitrogen, available phosphorus, exchangeable potassium and cation exchange capacity. The critical levels of nutrients in Nigeria soils reported by Esu (1991) were N (0.2 g/kg), P (20.0 mg/kg), K (0.3 cmol/kg), Zn (1.0 mg/kg), Cu (1.0 mg/kg), Fe (3.5 mg/kg), B (0.5 mg/kg), Mo (3.0 mg/kg). Furthermore, it was moderately acidic and classified as sandy loam in texture (Table 1).

Growth parameters and fresh biomass

Potassium fertilizer significantly improved the length of primary vines throughout the sampling periods (Table 2). At 14 weeks after planting, plants treated with 180 kg K_2O/ha had the longest mean vine length (184.93 cm), while the significantly shortest vine lengths were recorded in plants that did not receive any fertilizer (133.67 cm) and those that received 60 kg K_2O/ha (134.20 cm). However, those that received 150 and 180 kg K_2O/ha were not significantly different.

The number of leaves on the sweet potato plants was significantly influenced only by the high levels of K fertilizer. At 14 WAP, the application of 180 kg K_2O/ha resulted in the highest number of leaves which was significantly higher than the other treatments except 150 kg K_2O/ha (Table 3). Fresh shoot biomass increased with higher rates of K fertilizer application Plants that received 180 kg K_2O/ha exhibited the highest fresh shoot biomass (12 t/ha), whereas those without fertilizer recorded the least fresh biomass (7.1 t/ha). Treatments 150 and 180 kg K_2O/ha were not significantly different from each other (Table 4).

Yield parameters

The highest number of tubers (68) was recorded in plants that received 180 kg K_2O/ha, while the least number of tubers (46) was observed in plants that received 90 kg K_2O/ha. Also, treatments 60, 120, 150, and 180 kg K_2O/ha were not significantly different with regards to the number of tubers (Table 4).

The tuber weight increased with higher rates of K fertilizer application. Plants treated with 180 kg K_2O/ha produced the highest tuber yield at 13.2 t/ha that is not significantly different from 150 kg K_2O/ha, whereas those without fertilizer showed the lowest tuber yield 7.6 t/ha. The tuber yield in the unfertilized group was not significantly different from that in the groups treated with 60 and 120 kg K_2O/ha (Figure 1).

Table 1: Chemical and physical properties of the soil of the experimental site

Parameter	Values
pH (1:1) H_2O	5.9
Organic carbon (g/kg)	1.20
Total N (g/kg)	0.21
Available P (mg kg^{-1})	6.54
Exchangeable cations (C mol/kg)	
Calcium	3.11
Magnesium	0.8
Potassium	0.11
Particle size distribution (g/kg)	
Sand	770
Silt	95
Clay	135
Textural Class	Sandy loam

Table 2: Effects of potassium fertilizer rates on the length of primary vines of sweet potato

	Time of sampling (Weeks after planting)				
Fertilizer rates (kg K_2O/ha)	6	8	10	12	14
0	64.80	90.43	106.30	119.57	133.67
60	65.43	90.30	97.27	115.77	134.20
90	60.63	85.23	106.03	120.80	142.77
120	71.97	107.49	122.40	146.03	168.87
150	87.77	113.30	132.20	157.83	180.00
180	77.20	111.80	129.50	163.47	184.93
$LSD_{(0.05)}$	14.63	23.43	32.61	37.43	39.53

Table 3: Effects of potassium fertilizer rates on the number of leaves of sweet potato

	Time of sampling (Weeks after planting)				
Fertilizer rates (kg K_2O/ha)	6	8	10	12	14
0	73	99	114	126	145
60	75	97	111	123	137
90	71	108	123	135	157
120	77	105	121	138	164
150	97	140	158	172	199
180	109	146	169	188	217
$LSD_{(0.05)}$	29	30	34	30	36

Table 4: The effects of potassium fertilizer rates on the yield parameters of sweet potato

Fertilizer rates (kg K_2O/ha)	Number of tuber	Fresh shoot biomass (t/ha)
0	58	11.83
60	60	12.33
90	46	13.17
120	58	13.67
150	63	17.17
180	68	21.17
LSD $_{(0.05)}$	22	5.0

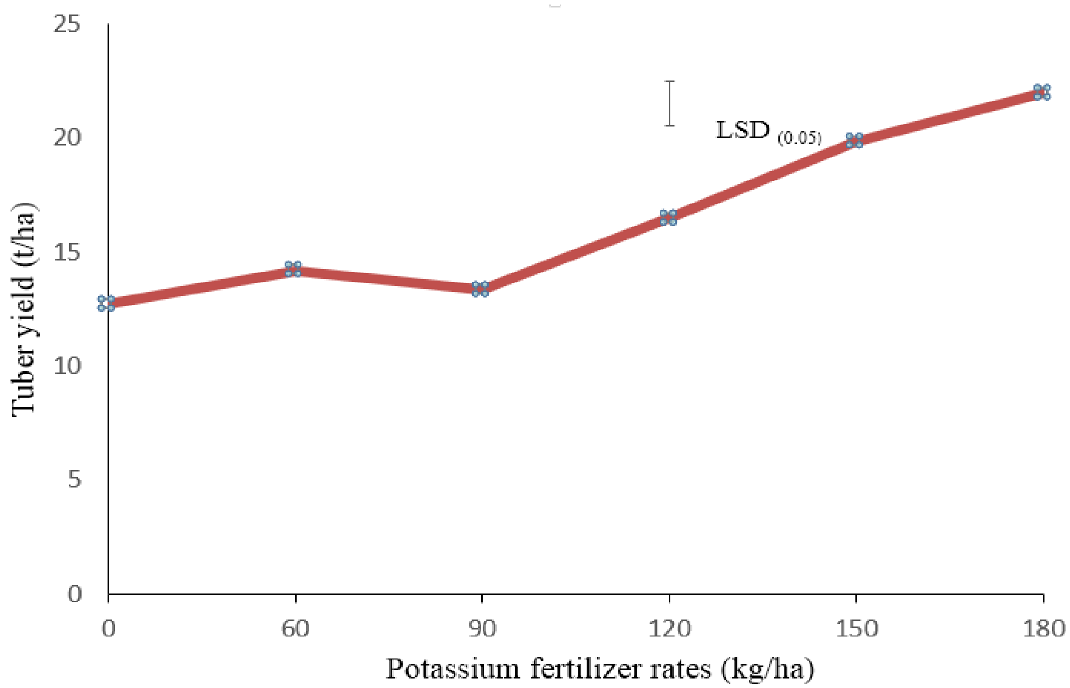

Figure 1: The effects of potassium fertilizer rates on the tuber yield of sweet potato

Nutritional Quality of Sweet Potato

Although, the carbohydrate content was not significantly influenced by the application of K fertilizer rates ($p < 0.05$), however, the highest carbohydrate content (68.76%) was recorded in plants that received 60 kg K_2O/ha, and the least carbohydrate content (62.96%) was observed in plants that received 180 kg K_2O/ha.

Crude fibre was significantly influenced by K fertilizer rates ($p < 0.05$); the highest crude fibre content (4.36%) was recorded in plants that received both 120 and 180 kg K_2O/ha, while the least (3.5%) was recorded in plants that received no fertilizer.

Carotenoid was progressively reduced as K rates increased, although, the reduction across treatments was not significant ($p > 0.05$). The control treatment exhibited the highest carotenoid content (2.19 mg/kg). Protein content were not significantly different across treatments, which shows that potassium did not affect the tuber protein content.

Tuber phosphorus content was not significantly affected by K fertilizer rates ($p > 0.05$). The potassium content in tuber increased as K fertilizer applied increased. The highest potassium content (1.26 mg) was recorded in plants that received 180 kg K_2O/ha, and the least potassium content (0.85 mg) was observed in plants that received no fertilizer (Table 5).

Table 5: The effects of potassium fertilizer rates on the nutritional quality of sweet potato tuber

Fertilizer Rates (kgK_2O/ha)	Protein (%)	CHO (%)	CF (kcal/kg)	Carotenoid (mg/kg)	P (%)	K (%)
0	10.71	67.00	3.50	2.14	0.09	0.85
60	10.67	68.76	3.71	2.10	0.09	0.94
90	10.24	65.49	4.16	1.88	0.09	1.10
120	10.58	64.61	4.36	1.98	0.09	1.10
150	10.27	62.22	3.93	1.96	0.10	1.23
180	10.57	62.96	4.36	1.86	0.08	1.26
LSD $_{(0.05)}$	ns	Ns	0.77	ns	ns	0.24

Discussion

The pre planting soil analysis showed that the soil was moderately acidic, characterized by low levels of organic carbon, available phosphorus, total nitrogen, and exchangeable potassium. These values were lower than the critical levels established in the soils of southwest Nigeria (Ojeniyi *et al*., 2012). This justifies the application of external fertilizer. The observation in this study that potassium fertilizer rates significantly affected the length of primary vines of sweet potato throughout the sampling period, is consistent with the well-established role of potassium as a key nutrient for plant growth and development. This finding corroborates the observations of Adebayo *et al.* (2022), who reported a 15% increase in vine length of sweet potato plant with the application of 180 kg K_2O/ha compared to the control. Similarly, studies by Setiawati *et al.* (2020) and Adu-Gyamfi *et al*. (2021) also noted that there is a positive relationship between potassium fertilizer rates and vine length in sweet potatoes. Furthermore, the observed significant increase in the number of leaves with increasing potassium fertilizer rates aligns with the report by Adeniji *et al.* (2018), who attributed this phenomenon to the enhanced vegetative growth of sweet potato plant promoted by potassium. Likewise, Msolla *et al.* (2014) observed that higher potassium fertilizer rates resulted in a greater number of leaves compared to the control. This finding strengthens the evidence for the crucial role of potassium in leaf development. The study's finding that fresh biomass weight significantly increased with higher potassium fertilizer rates further underscores the importance of potassium for sweet potato growth and development. This aligns with the findings of Pushpalatha *et al.* (2017), who reported a 25% increase in fresh biomass with the application of 160 kg K_2O/ha compared to the control. Uwah *et al*. (2018) also observed a similar increase with 120 kg K_2O/ha. This positive effect of potassium on fresh biomass is likely attributed to its role in water transport, cell expansion, and turgor regulation. The significant impact of potassium fertilizer on both the number of tubers and their weights further highlights its critical role in various vital plant processes, including photosynthesis, water transport, and resistance to pests and diseases. This finding is supported by Uwah *et al*. (2019), who reported a significant increase in the number of tubers per plant with increasing K fertilizer rates up to 160 kg K_2O/ha. Similarly, Zelelew *et al.* (2016) observed a 1.5-foldincrease in the number of tubers per plant at the highest K fertilizer rate (300 kg K_2O/ha) compared to the control. These studies collectively indicate that K fertilizer can substantially boost tuber production and weight in sweet potatoes.

Increasing potassium fertilizer rates did not significantly affect protein content, which is in conformity with the understanding that potassium is not directly involved in protein synthesis and that protein content is primarily limited by other factors like nitrogen availability. This observation is consistent with the findings of Adebayo *et al*. (2022) and Adu-Gyamfi *et al*. (2021), indicating that potassium fertilizer alone may not significantly influence protein content when other limiting factors are present. Similarly, the lack of significant effects of potassium fertilizer rates on carbohydrate and carotenoid content agree with observations by Arcilla *et al*. (2016), who suggested that nutritional components may not be directly influenced by potassium levels.

The potassium fertilizer rates had the potential to enhance the crude fibre content in sweet potatoes. This finding may be attributed to the increased nutrient availability promoting the continuous synthesis of crude fibre. Igbaekemen *et al.* (2018) and Adu-Gyamfi *et al.* (2021), reported similar observations and attributed the increase in crude fibre content to the combined effects of potassium on cell wall synthesis and strength. As expected, the potassium content in the tuber increased with increasing potassium fertilizer application, consistent with the findings of Etana *et al.* (2022). This is attributed to the higher supply of available potassium in the soil, highlighting its direct role in various physiological processes within the plant. Phosphorus content was not significantly affected by potassium fertilizer rates, possibly due to the presence of adequate levels of available phosphorus in the studied soil. This is similar to the findings of Smith (2020) and Johnson and Garcia (2019), suggesting that phosphorus levels in sweet potato crops may be less responsive to variations in potassium fertilization.

Conclusion and Recommendation

In conclusion, application of 180 kg K_2O/ha improved the performance of sweet potato better than the other rates in the study area. However, it seems that the maximum yield potential of sweet potato in the study area had not been attained. Therefore, further research with higher than 180 kg K_2O/ha may be required to identify the optimal level for cultivating sweet potatoes.

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