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Optimization of N, P and K Fertilization for Orange-Fleshed Sweet Potato (*Ipomoea batatas* (L) Lam) Production at Ikwo Abakaliki, Southeast Nigeria

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ABSTRACT

Orange-fleshed Sweet potato (*Ipomoea batatas* (L) Lam) is one of the most important crops for human consumption and livestock feed. All parts of the plant are useful for human consumption, animal feed and industrial uses. This research was conducted on a degraded Ultisol at the Teaching and Research Farm, Faculty of Agriculture, Alex Ekwueme Federal University, Ndufu-Alike (AEFUNAI), Abakaliki Ebonyi state during 2022 and 2023 planting seasons, to determine the optimum rate of N, P and K Fertilization for Orange-Fleshed Sweet Potato (*Ipomoea batatas* (L) Lam) Production at Ikwo Abakaliki, Southeast Nigeria. The treatments comprised of Nitrogen fertilizer (Urea with 46% N) applied at four levels namely 0, 45, 90, and 135 kg N/ha; Phosphorus fertilizer (Triple Super Phosphate with 20% P) applied at four levels namely 0, 15, 30, and 45kg P_2O_5/ha and Potassium fertilizer (Muriate of Potash with 50% K) applied at four levels namely 0, 20, 40, and 60 kg K_2O/ha. The treatments were combined to give 64 treatment combinations with three (3) replicates. The experiment was factorial experiment laid out in a Randomized Complete Block Design (RCBD). Data were collected on vine length (cm), number of leaves, number of branches, weight of storage root/plot (kg/plot) and total storage root yield (t/ha) and subjected to ANOVA for factorial experiment in RCBD at 5% probability level. The results showed that the various combined rates of NPK fertilizer significantly ($P < 0.05$) increased all the growth and yield parameters of orange-fleshed sweet potato compared to the control during two years of experiment. Also, the results of 2023 planting season were better than that of 2022 planting season. However, the application of NPK at the rate of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest number of OFSP leaves (374.3 and 388.0), number of OFSP branches (19 and 20.33), vine length of OFSP (457.0cm and 444.7cm), weight of OFSP storage root (3.070kg/plot) and (3.5kg/plot) and total storage root yield (3.255t/ha) and (3.88t/ha) in 2022 and 2023 respectively. NPK fertilizer application at the rate of 90kgN-45kgP_2O_5-60kgK_2O appeared appropriate for optimum yield for orange-fleshed sweet potato production in the study area and is therefore recommended.

1.0 Introduction

According to CIP (2018), the sweet potato is the sixth most important crop in the world. Nigeria is the third largest producer in the world after China and Uganda with an annual production estimated at 4.45 million metric tons per year and second in Sub-Sahara Africa after Malawi (FAOSTA, 2021). The increasing potential of the crop in poverty alleviation and food security due to its high productivity per unit area and time makes sweet potato an important crop for the survival of the resource poor farmers in Nigeria (NRCRI, 2009). Sweet potato supplies vital nutrients such as carbohydrates, proteins, minerals, and vitamins (Stathers et al., 2005). Its storage roots provide 25-30% as carbohydrates and 2.5-7.5% as protein of its dry weight, respectively. It also provides 200-300 mg 100 g^{-1} of potassium (K), 0.8 mg 100 g^{-1} of iron (Fe), 11 mg 100 g^{-1} of calcium (Ca) and 20-30 mg 100 g^{-1} of vitamin C of its dry matter (Çalifikan et al., 2007) as well copper, zinc, and manganese. B2, B6 and E, while the orange fleshed storage roots provide pro-vitamin A (Neela and Fanta 2019). . It can also be used as starch, natural colorants, and fermented products, such as Wine, ethanol, lactic acid, acetone, and butanol (Duvernaya et al., 2013). Orange fleshed sweet potato (OFSP) are gaining great attention as a means of mitigating common health related problems associated with vitamin A deficiency in low income households. This is due to the high nutritive value of beta-carotene, a precursor to vitamin A synthesis (Ukpabi *et al,* 2012). Orange-fleshed sweetpotato varieties are rich in micronutrients, particularly β-carotene, a precursor for vitamin A, and their consumption contributes to combat vitamin A deficiency and also serves as a good source of energy, calcium, iron, vitamins and some minerals (Low et al. 2009). OFSP also has powerful antioxidants that help prevent cancers, as well as natural sugars. Sweetpotato leaves are widely consumed as vegetables, stems are used as planting material, and storage roots are consumed either boiled or roasted (Low et al. 2009).

OFSP production in Nigeria is still bedeviled with numerous challenges such as low yield. The average yield of the crop is still within a very low range of 4.0 t/ha compared with average yield values of 15 – 30 t/ha obtainable from like China (Odebode, 2004). The high yielding orange fleshed sweetpotato varieties are fertilizer responsive (Nedunchezhiyan et al., 2010). Fertilizer application is an important option left to farmers for yield improvement in most soils. The potential of sweet potato as a cash crop has led to the requirements of fertilizer recommendations for commercial farmers to increase root yield. However, fertilization needs to be done rationally to avoid negative ecological impacts and undesirable effects on the sustainability of agricultural systems. Nitrogen (N) is one of the nutrients most required by sweet potato (Ukom et al., 2009). This element plays a key role in the growth, yield, and quality of storage roots, mainly because it influences the production and partition of dry matter (DM) in the plant (Okpara et al., 2009). Adequate N supply improves shoot development and increases the leaf area index, favoring the photosynthesis of sweet potato plants and the synthesis of carbohydrates and proteins (Okpara et al., 2009; Ukom et al., 2009). Phosphorus (P) is next to nitrogen in importance and is required by plants in large amounts. It is an important element in providing cellular energy for biochemical synthesis in plant (Cruz et al., 2016). It is vital for root development and tuber formation (Agri-Farming 2023). Potassium (K) is an important nutrient for sweet potato for its role in enzymatic activation and in carbohydrate formation and conversion into starch, besides acting in the transport of photo-assimilates from the leaves to the storage organs (Okpara et al., 2009). Thus, K acts positively on the mass and flavor of storage roots, improving product quality and market value (Marschner, 2012) and increase carotenoid content in orange fleshed cultivars (Okpara et al., 2004).

However, there are results that showed that the application of N, P and K fertilizers, singly or mixed, can increase growth and yield of sweet potato, but little or no study has evaluated the optimum rates of fertilizer combination rates of nitrogen, phosphorus and potassium for orange flesh sweet potato production in Ikwo, Abakaliki, Southeastern Nigeria

2.0. Materials and Methods

2.1. Experimental site

The field experiments were carried out in 2022 and 2023 planting seasons at the Teaching and Research Farm, Faculty of Agriculture, Alex Ekwueme Federal University, Ndufu-Alike (AEFUNAI), Abakalilki Ebonyi state, located at approximately Latitudes 06˚ 07' 34" N and 06˚ 07' 40" N and Longitudes 08˚ 08' 09" E and 08˚ 08' 14" E with altitude of 142 m above sea level. The climate is essentially tropical humid with a total rainfall of 2168 mm per annum, annual average temperature of about 27°C and annual relative humidity of between 60-80%. The rainfall pattern is bimodal: a long wet season from April to July is interrupted by a short “August break” followed by another short rainy season from September to October or early November. Dry season stretches from early November to March (AE-FUNAI Meteorology station, 2020).The soil of the experimental site is well-drained sandy clay loam. They are Ultisol and are strongly weathered acidic soil with low cation exchange capacity, low base saturation, low organic matter and low total nitrogen (Federal Department of Agriculture and land Resources 1985).plot was 3 × 2 m. Blocks were 1 m apart and plots were 0.5 m apart.

2.2. Experimental layout.

The experimental field was cleared manually using cutlass and thrashed removed from the site before mechanical (ploughing and harrowing) land preparation after which plots were marked out to the required plot size of 3 × 2 m. Poultry manure was obtained from the poultry section of the Landmark University Teaching and Research Farm. Fresh top Mexican sunflower was collected from a nearby farm containing green tender stems and leaves. Cabbage residue was collected from the sequel to cabbage harvest in Landmark University screen house. The manures were weighed and thereafter incorporated into the soil to a depth of approximately 20 cm. The plots were allowed for 3 weeks for equilibration of amendments before sowing of golden melon seeds.

The sowing of golden melon seeds was done in late May 2020. Two seeds were sown per hole at inter-row spacing of 0.5 m and 0.5 m intra-row spacing and later thinned to one to give a plant population of 40,000 plants ha^{-1}. Manual weeding was done starting from two weeks after planting and continued fortnightly using hoes while insect pests were controlled by spraying cypermethrin weekly at the rate of 30 ml per 10 L of water from 2 weeks and thereafter based on needs bases

2.3. The experimental treatments

The treatments comprised of Nitrogen fertilizer (Urea with 46% N) applied at four levels namely 0, 45, 90, and 135 kg/ha; Phosphorus fertilizer (Triple Super Phosphate with 20% P) applied at four levels namely 0, 15, 30, and 45kg/ha and Potassium fertilizer (Muriate of Potash with 50% K) applied at four levels namely 0, 20, 40, and 60 kg/ha, which were sourced from the Ebonyi state fertilizer and chemical company Abakaliki, Ebonyi state. The treatments were combined to give 64 treatment combinations, replicated three (3) times.

2.4. Planting Material and Treatment Application

The test crop for the experiment is Orange Flesh Sweet Potato (UMUSPO 3) commonly called Mother Delight, were sourced from National Root Crop Research Institute, Umudike. The treatments were applied at 4 weeks after planting of the Orange Flesh Sweet Potatoes (Mother's Delight) vines. The vine cuttings of 20cm length were planted at a spacing of 0.3m along the crest of the ridge. Supplying was done two weeks after planting (WAP). Weeding was done manually with hoe at 6 and 10 weeks after planting (WAP). The ridges were earthed up to avoid exposure of the orange flesh sweet potato roots.

2.5. Data Collection

Orange flesh sweet potato growth and data were collected as follows: (a) Vine length was taken using a measuring tape from the base of the plant vine to the tip of the vine. (b) Number of leaves was taken by counting (c) Number of branches was taken by counting (d) Weight of storage root/plot (kg/plot) at harvest were taken with a weighing balance, and (f) Total storage root yield (t/ha) at harvest were taken with a weighing balance.

2.6. Data Analysis

All the data collected were subjected to Analysis of variance (ANOVA) for factorial experiment in Randomized Complete Block Design (RCBD) using GenStat statistical package 17th Edition (GenStat, 2014) and the treatment means were separated using the Fisher's Least Significant Different (FLSD) at 5% probability level.

3.0. Results and Discussion

3.1. Physico-Chemical Properties of the Soil Used For the Study

The properties of the experimental soil (Table 1) indicate that the soil is sandy loam, slightly acidic, with low organic carbon, nitrogen, exchangeable bases and high available phosphorus. This suggests that the soil is low in fertility.

3.2. Effect of NPK fertilizer on Number of leaves in 2022 and 2023 planting seasons

The effect of NPK fertilizer on the number of OFSP leaves in 2022 and 2023 planting seasons are shown in Table 2. The various rates of NPK fertilizer applied significantly ($P < 0.05$) recorded higher number of OFSP leaves over control in 2022 and 2023 planting seasons. The application of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest number of OFSP leaves (374.3 and 388.0) in 2022 and 2023 respectively.

The increased number of OFSP leaves might be attributed to the fact that N helps in the building of leaf tissues and cell multiplication, P plays a critical role in leaf initiation and K increased photosynthetic activity in OFSP plant. The observed significant positive performance in number of OFSP leaves with application of NPK fertilizer could also be attributed to the quick release of essential nutrient elements supplied, which resulted in increased photosynthetic efficiency. The increased number of OFSP leaves in 2023 over 2022 might be due to the residual effect of the NPK fertilizer applied in 2022 and crop residues from 2022 planting, which contributed to greater improvement in 2023.

Similar results were obtained from Sebastiani et al (2006) who reported that a dose of 50-75kg N, 25-50kg P_2O_5 and 60-90kg K_2O per hectare is optimum for sweet potato production; Ambecha (2011) stated that the use fertilizer vary from region to region and the experience of some African countries may applied in other countries which is 35 – 45kg ha^{-1} N, 50-100kg ha^{-1} P_2O_5 and 60-180kgK ha^{-1} and Mahmuddin, et al., (2019) observed an increased tuber yield and growth of improved sweet potato with mineral fertilizer dosage of 50 kg N ha^{-1}, 50 kg P2O5 ha^{-1} and 60 kg K2O ha^{-1} at Indonesia.

Also, the application of fertilizer beyond the rate of 90kgN-45kgP_2O_5-60kgK_2O showed a reduction in the number of OFSP leaves at 4, 8 and 12 WATA in both 2022 and 2023 planting seasons. This might be due the quantity of fertilizer applied was beyond the optimum level resulting in toxicity to plant, thereby decreasing OFSP foliage production. This is in line with Havlin *et al.,* (2005) who reported that an application of plant nutrient above the optimum level causes plant to take up more of the nutrient than needed for their growth and development, results in toxicity in plant, which might lead to reduced growth and death of plants

Table 1: Some Physico-chemical Properties of the Soil before Treatment Application

Soil Properties	2022	2023
Sand (%)	59.60	60.00
Silt (%)	20.10	20.00
Clay (%)	20.30	20.00
Textural class	Sandy-loam	Sandy loam
Soil pH (water)	5.92	5.97
Soil pH ($CaCl_2$)	5.08	5.22
Organic carbon (%)	0.69	0.72
Organic matter (%)	1.18	1.24
Total nitrogen (%)	0.16	0.18
C:N ratio	4.31	4.0
Available phosphorus (mg kg^{-1})	28.20	28.30
Ca^{2+} ($cmol^{-1}$ kg^{-1})	1.65	1.7
Mg^{2+} ($cmol^{-1}$ kg^{-1})	0.88	0.92
K^{+} ($cmol^{-1}$ kg^{-1})	0.112	0.124
Na^{+} ($cmol^{-1}$ kg^{-1})	0.225	0.251
Total Exchangeable bases (TEB) ($cmol^{-1}$ kg^{-1})	2.867	2.995
Exchangeable acidity ($cmol^{-1}$ kg^{-1})	2.64	2.38
Effective cation exchange capacity (ECEC) ($cmol^{-1}$ kg^{-1})	5.507	5.375
Percentage base saturation (%)	52.06	55.72

Table 2: Effect of NPK fertilizer on Number of leaves in 2022 and 2023 planting seasons

K (kg/ha)		0	20	40	60	Mean	0	20	40	60	Mean
N (kg/ha)	P (kg/ha)	2022 planting season					2023 planting season				
0	0	73.7	88.3	93.0	98.3	88.3	86.0	94.0	101.0	104.0	96.2
	15	104.7	107.7	110.7	114.0	109.2	109.0	113.0	114.0	117.0	113.2
	30	117.7	124.7	129.3	135.7	126.8	119.0	126.0	137.0	142.0	131.0
	45	138.7	143.7	148.3	157.3	147.0	148.0	156.0	159.0	168.0	157.7
45	0	201.0	209.0	214.0	219.7	211.2	225.2	232.0	238.0	242.0	234.5
	15	225.3	229.7	236.3	241.7	233.2	245.0	248.0	251.0	256.0	250.0
	30	249.7	254.0	257.7	259.7	255.2	259.0	272.0	278.0	283.0	272.9
	45	266.7	278.3	282.3	287.7	278.7	287.0	291.0	296.0	299.0	293.2
90	0	291.7	296.3	313.0	318.3	304.8	304.0	312.0	323.0	327.0	316.5
	15	321.7	326.3	329.7	331.3	327.2	332.0	336.0	339.0	346.0	338.2
	30	335.3	342.3	347.7	354.7	345.0	348.0	354.0	358.0	367.0	356.7
	45	358.3	366.3	370.7	374.3	367.5	371.0	376.0	382.0	388.0	379.2
135	0	277.7	281.3	288.3	291.7	284.7	306.0	310.0	315.0	322.0	313.2
	15	296.0	298.0	301.3	303.7	299.7	327.0	328.0	335.0	338.0	332.0
	30	307.3	310.7	315.7	317.7	312.8	342.0	347.0	352.0	359.0	350.0
	45	319.7	322.0	326.3	329.7	324.4	363.0	368.0	373.0	379.0	370.7
Mean		242.8	249.5	254.1	258.5		260.7	267.2	271.9	277.3	

2022	2023
LSD (0.05) for N = 0.5098	LSD (0.05) for N = 0.3061
LSD (0.05) for P = 0.5098	LSD (0.05) for P = 0.3061
LSD (0.05) for K = 0.5098	LSD (0.05) for K = 0.3061
LSD (0.05) for N*P =1.019	LSD (0.05) for N*P = 0.6122
LSD (0.05) for N*K =1.019	LSD (0.05) for N*K = 0.6122
LSD (0.05) for P*K = 1.019	LSD (0.05) for P*K = 0.6122
LSD (0.05) for N*P*K = 2.041	LSD (0.05) for N*P*K = 1.2244

3.3. Effect of NPK fertilizer on Number of branches in 2022 and 2023 planting seasons

The effect of NPK fertilizer on the number of OFSP branches in 2022 and 2023 planting seasons are shown in Table 3. The various rates of NPK fertilizer applied significantly ($P < 0.05$) recorded higher number of OFSP branches over control in both 2022 and 2023 planting seasons. The application of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest number of OFSP branches (19 and 20.33) in 2022 and 2023 respectively.

The numerical increase in the OFSP branches might probably be due to the enhanced metabolic processes as a result of the optimum nutrients supplied by the NPK fertilizer. The increased number of OFSP branches might also be due to the adequate supply of N, P and K promote higher photosynthetic activity and vigorous vegetative growth and promotes the chance for emergence of new vines. The increased numbers of OFSP branches in response to the increased rate of NPK fertilizer application might be attributed to increased concentration of nutrient in the soil that may have enhanced root uptake of the nutrient possibly resulting in increased concentration of chlorophyll in the leaves, heightened rate of photosynthesis, high rate of leaf expansion, increased leaf number, increased number of branches and dry matter accumulation. The increased number of OFSP branches in 2023 over 2022 might be due to the residual effect of the NPK fertilizer applied in 2022 and increased soil organic matter contributed from crop residues from 2022 planting, which contributed to greater improvement in 2023 than 2022.

Similar results were obtained from Sebastiani et al (2006) who reported that a dose of 50-75kg N, 25-50kg P_2O_5 and 60-90kg K_2O per hectare is optimum for sweet potato production; Mahmuddin, et al., (2019) observed an increase in number of branches of improved sweet potato with mineral fertilizer dosage of 50 kg N ha^{-1}, 50 kg P2O5 ha^{-1} and 60 kg K2O ha^{-1} at Indonesia. Also, the application of fertilizer beyond the rate of 90kgN-45kgP_2O_5-60kgK_2O showed a reduction in the number of OFSP branches at 4, 8 and 12 WATA in both 2022 and 2023 planting seasons. This might be due the quantity of fertilizer applied was beyond the optimum level resulting in toxicity to plant, thereby decreasing OFSP number of branches. This is in line with Havlin *et al.,* (2005) who reported that an application of plant nutrient above the optimum level causes plant to take up more of the nutrient than needed for their growth and development, results in toxicity in plant, which might lead to reduced growth and death of plants.

Table 3: Effect of NPK fertilizer on Number of branches in 2022 and 2023 planting seasons

K (kg/ha)		0	20	40	60	Mean	0	20	40	60	Mean
N (kg/ha)	P (kg/ha)	2022 planting season					2023 planting season				
0	0	6.33	12.00	12.00	12.33	10.64	6.33	12.00	12.00	12.33	10.64
	15	12.67	13.00	12.33	13.33	12.83	14.33	14.33	14.33	14.67	14.42
	30	13.33	14.00	14.33	14.33	14.00	14.67	14.67	15.00	15.67	15.00
	45	14.33	14.33	14.33	14.33	14.33	15.67	15.67	15.67	15.67	15.67
45	0	14.29	15.00	15.00	15.00	14.80	15.56	16.00	16.33	16.33	16.00
	15	16.00	16.33	16.33	17.00	16.67	17.00	17.00	17.00	17.67	17.17
	30	17.00	17.00	17.00	17.00	17.00	17.67	17.67	17.67	18.33	17.83
	45	17.33	17.33	17.33	17.33	17.33	18.67	18.67	18.67	18.67	18.67
90	0	17.67	17.67	17.67	17.67	17.67	19.00	19.00	19.00	19.00	19.00
	15	17.67	17.67	18.67	18.67	18.17	19.00	19.67	20.00	20.00	19.66
	30	18.87	18.67	18.67	18.67	18.75	20.00	20.00	20.00	20.00	20.00
	45	18.67	18.67	18.67	19.00	18.67	20.00	20.00	20.00	20.33	20.08
135	0	15.67	15.67	16.00	15.67	15.75	17.00	17.00	17.33	17.00	17.08
	15	16.00	16.00	16.33	16.33	16.17	17.33	16.67	17.00	17.00	17.00
	30	16.33	16.67	16.67	17.33	16.75	17.00	17.33	18.00	18.00	17.58
	45	17.33	17.67	17.00	17.33	17.33	18.00	18.33	18.00	18.00	18.08
Mean		15.64	16.15	16.15	16.31		16.70	17.21	17.21	17.20	

2022	2023
LSD (0.05) for N = 0.2186	LSD (0.05) for N = 0.2244
LSD (0.05) for P = 0.2186	LSD (0.05) for P = 0.2244
LSD (0.05) for K = 0.2186	LSD (0.05) for K = 0.2244
LSD (0.05) for N*P =0.4372	LSD (0.05) for N*P = 0.4488
LSD (0.05) for N*K =0.4372	LSD (0.05) for N*K = 0.4488
LSD (0.05) for P*K = 0.4372	LSD (0.05) for P*K = 0.4488
LSD (0.05) for N*P*K = 0.8752	LSD (0.05) for N*P*K = 0.8983

3.4. Effect of NPK fertilizer on vine length in 2022 and 2023 planting seasons

The effect of NPK fertilizer on the vine length of OFSP in 2022 and 2023 planting seasons are shown in Table 4. The various combined rates of NPK fertilizer applied significantly ($P < 0.05$) recorded higher vine length of OFSP over control in both 2022 and 2023 planting seasons. The application of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest vine length of OFSP (457.0cm and 444.7cm) in 2022 and 2023 respectively.

The increased vine length of OFSP might be due to adequate supply of N, P and K from the applied fertilizer which resulted to high photosynthetic activity and vigorous vegetative growth thereby increasing internodes lengths. Also, the highest vine length observed could be due to the presence of adequate amount of N, P and K which resulted in better vegetative growth, greater photo assimilate, activation of photosynthesis and metabolic processes of organic compounds in plants for the production of increasing vine length. Increased vine length of OFSP might be due to increased cell division and elongation resulting in higher canopy development and better utilization of NPK fertilizer applied. The increased vine length of OFSP in 2023 over 2022 might be due to the residual effect of the NPK fertilizer applied in 2022 and increased soil organic matter contributed from crop residues from 2022 planting, which contributed to greater improvement in 2023 than 2022

Similar results were obtained from Sebastiani et al (2006) who reported that a dose of 50-75kg N, 25-50kg P_2O_5 and 60-90kg K_2O per hectare is optimum for sweet potato production; Ambecha (2011) stated that the use fertilizer vary from region to region and the experience of some African country may applied in our country which is 35 – 45kg ha-1 N, 50-100kg ha-1 P_2O_5 and 60-180kg K_2O ha^{-1} and Mahmuddin, et al., (2019) observed an increased tuber yield and growth of improved sweet potato with mineral fertilizer dosage of 50 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} at Indonesia.

Also, the application of fertilizer beyond the rate of 90kgN-45kgP_2O_5-60kgK_2O showed a reduction in the vine length of OFSP at 4, 8 and 12 WATA in both 2022 and 2023 planting seasons. This might be due the quantity of fertilizer applied was beyond the optimum level resulting in toxicity to plant, thereby affecting the OFSP vine length. This is in line with Havlin *et al.,* (2005) who reported that an application of plant nutrient above the optimum level causes plant to take up more of the nutrient than needed for their growth and development, results in toxicity in plant, which might lead to reduced growth and death of plants.

Table 4: Effect of NPK fertilizer on vine length in 2022 and 2023 planting seasons

K (kg/ha)		0	20	40	60	Mean	0	20	40	60	Mean
N (kg/ha)	P (kg/ha)	2022 planting season					2023 planting season				
0	0	157.0	209.0	212.6	217.3	198.6	188.0	245.0	250.3	255.3	234.4
	15	222.6	226.6	230.3	234.6	228.5	259.3	262.3	266.3	269.3	264.3
	30	238.3	242.6	248.3	253.6	245.7	271.3	273.7	276.3	278.3	274.9
	45	256.6	260.6	265.6	267.6	262.6	279.0	279.3	280.0	282.0	280.1
45	0	280.3	297.0	295.3	302.3	293.3	301.9	317.0	309.0	313.7	309.7
	15	306.3	316.0	323.0	328.0	318.2	316.7	321.7	331.7	331.7	325.4
	30	335.0	339.6	344.3	349.3	342.0	341.0	344.3	350.3	358.0	348.4
	45	353.3	358.0	361.0	363.6	358.9	360.7	363.7	370.7	373.0	367.0
90	0	367.6	371.3	376.6	381.6	374.3	379.7	384.7	388.7	357.3	377.6
	15	385.6	390.3	393.6	397.0	391.6	393.7	395.7	400.7	404.7	398.7
	30	402.6	406.3	415.6	433.0	414.3	408.7	413.7	418.7	427.7	417.1
	45	438.0	444.3	452.3	457.0	447.8	435.7	438.7	441.7	444.7	440.2
135	0	360.6	363.3	369.0	367.0	365.0	377.7	379.7	382.7	385.7	381.4
	15	377.3	377.0	374.6	382.6	377.9	389.7	390.7	393.7	394.7	392.2
	30	385.3	392.6	397.3	390.3	391.4	398.7	402.7	405.0	409.7	404.0
	45	406.0	434.0	443.0	456.0	432.6	412.3	416.7	423.0	428.0	420.0
Mean		329.1	339.7	343.4	346.2		344.6	352.6	355.5	357.1	

2022	2023
LSD (0.05) for N = 3.385	LSD (0.05) for N = 4.429
LSD (0.05) for P = 3.385	LSD (0.05) for P = 4.429
LSD (0.05) for K = 3.385	LSD (0.05) for K = 4.429
LSD (0.05) for N*P =6.771	LSD (0.05) for N*P = 8.857
LSD (0.05) for N*K =6.771	LSD (0.05) for N*K = 8.857
LSD (0.05) for P*K = 6.771	LSD (0.05) for P*K = 8.857
LSD (0.05) for N*P*K =13.57	LSD (0.05) for N*P*K = 17.73

3.5. Effect of NPK fertilizer on weight of storage root (kg/plot) of Orange Flesh Sweet Potato in 2022 and 2023 planting seasons

Table 5 shows the effect of NPK fertilizer on OFSP weight of storage root in 2022 and 2023 planting seasons. The various rates of NPK fertilizer applied significantly ($P < 0.05$) recorded higher weight of OFSP storage roots over control in both 2022 and 2023 planting seasons. The application of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest weight of OFSP storage root in 2022 (3.070kg/plot) and (3.5kg/plot) in 2023. This increased yield might be due to the photosynthetic capacity of the foliar cover, the ability of the crop to translocate the photo- assimilates of the leaf to the root. It is therefore possible that assimilation of photosynthesis translocated to the roots may have contributed to the high yields from the mineral fertilizer treatment. Adequate N supply improves shoot development, favoring the photosynthesis of sweet potato plants and the synthesis of carbohydrates, P facilitates cell division and promotes root development while K stimulate photosynthesis, and synthesis of large molecular weight substances within storage organs that may contribute to the rapid bulking of the roots, resulting in increased root yield. Increased OFSP yield might be due to the readily available macronutrients leading to the synthesis of more photo-assimilates, which is used in dry matter accumulation in OFSP root with the application of N, P and K fertilizer. The increased weight of OFSP roots in 2023 over 2022 might be due to the residual effect of the NPK fertilizer applied in 2022 and increased soil organic matter contributed from crop residues from 2022 planting, which contributed to greater improvement in 2023 than 2022

Similar results were obtained from SRI-CSIR (2003) that recommended the application of 90kgN-45kg P_2O_5-60kg K_2O per hectare for optimum sweet potato production in Ghana; Sebastiani et al, (2006) recommended the application of 50-75kg N, 25-50kg P_2O_5 and 60-90kg K_2O per hectare is optimum for root production in sweet potato; IFA, (1992) recommended the application of 35-65 kg N, 50-100 kg P_2O_5 and 60-120 kg K_2O per hectare in most countries and Mahmuddin, et al., (2019) observed an increased tuber yield and growth of improved sweet potato with mineral fertilizer dosage of 50 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} at Indonesia

Also, the application of fertilizer beyond the rate of 90kgN-45kgP_2O_5-60kgK_2O showed a reduction in the total storage root of OFSP in both 2022 and 2023 planting seasons. This might be due to the fact that high amount of N application reduces storage root development. Similar results were reported by Fernandes and Ribeiro (2020), Ukom *et al.,* (2009 and Ambecha (2011) that excess nitrogen increases gibberellin production, which causes increased foliage production at the expense of the formation of storage roots and may also lead to tuber cracking. This might also be due the quantity of fertilizer applied was beyond the optimum level resulting in toxicity to plant.

Table 5: Effect of NPK fertilizer on weight of storage root (kg/plot) of Orange Flesh Sweet Potato in 2022 and 2023 planting seasons

K (kg/ha)		0	20	40	60	Mean	0	20	40	60	Mean
N (kg/ha)	P (kg/ha)	2022 planting season					2023 planting season				
0	0	0.867	1.333	1.600	1.700	1.373	1.000	1.600	1.800	2.000	1.597
	15	1.900	1.950	1.950	1.950	1.937	2.500	2.550	2.550	2.550	2.537
	30	1.980	1.987	2.033	2.067	2.017	2.600	2.600	2.700	2.700	2.650
	45	2.067	2.083	2.097	2.097	2.086	2.700	2.750	2.750	2.750	2.737
45	0	2.135	1.800	2.133	2.133	2.074	2.750	2.750	2.800	2.800	2.777
	15	2.167	2.167	2.183	2.217	2.183	2.800	2.800	2.850	2.850	2.825
	30	2.217	2.217	2.217	2.217	2.217	2.850	2.850	2.850	2.850	2.850
	45	2.233	2.300	2.300	2.300	2.283	2.900	2.900	2.900	2.900	2.900
90	0	2.433	2.467	2.467	2.533	2.475	2.900	3.000	3.000	3.000	2.974
	15	2.567	2.700	2.733	2.733	2.683	3.100	3.100	3.200	3.200	3.150
	30	2.867	2.867	2.907	2.917	2.894	3.200	3.220	3.240	3.250	3.227
	45	2.967	3.067	3.067	3.070	3.041	3.300	3.350	3.350	3.500	3.449
135	0	2.433	2.533	2.533	2.533	2.508	3.100	3.200	3.200	3.200	3.174
	15	2.533	2.533	2.633	2.633	2.583	3.200	3.200	3.300	3.300	3.250
	30	2.663	2.683	2.767	2.817	2.732	3.330	3.350	3.400	3.450	3.382
	45	2.817	2.833	2.867	2.867	2.846	3.450	3.450	3.450	3.450	3.450
Mean		2.303	2.358	2.405	2.424		2.855	2.933	2.971	2.987	

LSD (0.05) for N = 0.04719	LSD (0.05) for N = 0.05230
LSD (0.05) for P = 0.04719	LSD (0.05) for P = 0.05230
LSD (0.05) for K = 0.04719	LSD (0.05) for K = 0.05230
LSD (0.05) for N*P = 0.09436	LSD (0.05) for N*P = 0.1460
LSD (0.05) for N*K = 0.09436	LSD (0.05) for N*K = 0.1460
LSD (0.05) for P*K = 0.09436	LSD (0.05) for P*K = 0.1460
LSD (0.05) for N*P*K = 0.1889	LSD (0.05) for N*P*K = 0.2920

3.6: Effect of NPK fertilizer on the Total Storage Root Yield (t/ha) of Orange Flesh Sweet Potato in 2022 and 2023 planting seasons

Table 6 shows the effect of NPK fertilizer on OFSP total storage root yield in 2022 and 2023 planting seasons. The various rates of NPK fertilizer applied significantly ($P < 0.05$) recorded higher OFSP total storage roots over control in both 2022 and 2023 planting seasons. The application of 90kgN-45kgP_2O_5-60kgK_2O recorded the highest OFSP total storage root yield in 2022 (3.255t/ha) and (3.88t/ha) in 2023. This increased yield might be due to the photosynthetic capacity of the foliar cover, the ability of the crop to translocate the photo- assimilates of the leaf to the root. It is therefore possible that assimilation of photosynthesis translocated to the roots may have contributed to the high yields from the mineral fertilizer treatment. Adequate N supply improves shoot development, favoring the photosynthesis of sweet potato plants and the synthesis of carbohydrates, P facilitates cell division and promotes root development while K stimulate photosynthesis, and synthesis of large molecular weight substances within storage organs that may contribute to the rapid bulking of the roots, resulting in increased root yield. Increased OFSP yield might be due to the readily available macronutrients leading to the synthesis of more photo-assimilates, which is used in dry matter accumulation in OFSP root with the application of N, P and K fertilizer. The increased total yield of OFSP roots in 2023 over 2022 might be due to the residual effect of the NPK fertilizer applied in 2022 and increased soil organic matter contributed from crop residues from 2022 planting, which contributed to greater improvement in 2023 than 2022

Similar results were obtained from SRI-CSIR (2003) that recommended the application of 90kgN-45kg P_2O_5-60kg K_2O per hectare for optimum sweet potato production in Ghana; Sebastiani et al, (2006) recommended the application of 50-75kg N, 25-50kg P_2O_5 and 60-90kg K_2O per hectare is optimum for root production in sweet potato; IFA, (1992) recommended the application of 35-65 kg N, 50-100 kg P_2O_5 and 60-120 kg K_2O per hectare in most countries and Mahmuddin, et al., (2019) observed an increased tuber yield and growth of improved sweet potato with mineral fertilizer dosage of 50 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} at Indonesia

Also, the application of fertilizer beyond the rate of 90kgN-45kgP_2O_5-60kgK_2O showed a reduction in the total storage root of OFSP in both 2022 and 2023 planting seasons. This might be due to the fact that high amount of N application reduces storage root development. Similar results were reported by Fernandes and Ribeiro (2020), Ukom *et al.,* (2009) and Ambecha (2011) that excess nitrogen increases gibberellin production, which causes increased foliage production at the expense of the formation of storage roots and may also lead to tuber cracking. This might also be due the quantity of fertilizer applied was beyond the optimum level resulting in toxicity to plant.

4.0. Conclusion

This study has demonstrated that orange-fleshed sweet potato production responded to the application of NPK fertilizer based on improved growth and root yield. The various rates of NPK fertilizer applied significantly ($P < 0.05$) increased the growth and yield parameters of OFSP over control in both 2022 and 2023 planting seasons. However, the application of 90kgN-45kgP_2O_5-60kgK_2O appeared appropriate for optimum yield in our study area.

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Table 6: Effect of NPK fertilizer on the Total Storage Root Yield (t/ha) of Orange Flesh Sweet Potato in 2022 and 2023 planting seasons

K (kg/ha)		0	20	40	60	Mean	0	20	40	60	Mean
N (kg/ha)	P (kg/ha)	2022 planting season					2023 planting season				
0	0	0.880	1.330	1.660	1.720	1.395	1.110	1.770	2.000	2.220	1.772
	15	1.770	1.830	1.830	1.830	1.815	2.770	2.830	2.830	2.830	2.815
	30	1.850	1.860	1.880	1.940	1.882	2.880	2.880	3.000	3.000	2.940
	45	1.940	1.940	1.960	1.960	1.950	3.000	3.050	3.050	3.050	3.037
45	0	1.990	1.990	1.990	1.990	1.990	3.060	3.060	3.110	3.110	3.087
	15	2.050	2.050	2.050	2.110	2.065	3.110	3.110	3.160	3.160	3.135
	30	2.110	2.110	2.110	2.110	2.110	3.160	3.160	3.160	3.160	3.160
	45	2.110	2.220	2.220	2.220	2.192	3.220	3.220	3.220	3.220	3.220
90	0	2.440	2.440	2.440	2.550	2.468	3.220	3.330	3.330	3.330	3.302
	15	2.550	2.770	2.900	3.000	2.804	3.440	3.440	3.550	3.550	3.495
	30	3.000	3.000	3.000	3.200	3.050	3.550	3.570	3.590	3.610	3.580
	45	3.200	3.250	3.250	3.250	3.237	3.660	3.880	3.880	3.880	3.824
135	0	2.200	2.200	2.200	2.200	2.200	3.440	3.550	3.550	3.550	3.522
	15	2.333	2.367	2.500	2.500	2.425	3.550	3.550	3.660	3.660	3.605
	30	2.500	2.550	2.600	2.600	2.562	3.700	3.720	3.770	3.830	3.755
	45	2.700	2.800	3.000	3.000	2.874	3.830	3.880	3.880	3.880	3.867
Mean		2.226	2.301	2.349	2.386		3.169	3.254	3.296	3.315	

2022	2023
LSD (0.05) for N = 0.004158	LSD (0.05) for N = 0.0044
LSD (0.05) for P = 0.004158	LSD (0.05) for P = 0.0044
LSD (0.05) for K = 0.004158	LSD (0.05) for K = 0.0044
LSD (0.05) for N*P = 0.008316	LSD (0.05) for N*P = 0.0088
LSD (0.05) for N*K = 0.008316	LSD (0.05) for N*K = 0.0088
LSD (0.05) for P*K = 0.008316	LSD (0.05) for P*K = 0.0088
LSD (0.05) for N*P*K = 0.01665	LSD (0.05) for N*P*K = 0.0176

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