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Influence of Plant Density and Different Fertilizers on Growth and Tuber Yield of Sweet Potato (*Ipomea batata. (L.)* Lam) in Savanna-Forest Zone of Nigeria

K.E[1*]. Muamba, J[2]. Kabeya, A.A[1]. Aliyu, S[1]. Tarimin, A[1]. Sati, S.N[1]. Dachi, J.E[1]. Chakven
[1]Department of Crop Production, University of Jos, Jos, Nigeria
[2]Department of Information Technology, University of Maryland, Adelphi, United State
Correspondence E-mail: muambakashalaeric@gmail.com

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Abstract
The study was conducted in Jos South local Government area of plateau State, to assess the impact of different nitrogen sources and plant densities on the yield of the UMUSP-3 variety of sweet potato. The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three times in a 4 x 4 factorial design, the experiment consisted of four plant densities (P1=20,000, P2= 25,000, P3= 33,333 and P4= 50,000 plants ha^{-1}) and four fertilizer types (Control, poultry manure, cattle manure and NPK fertilizer). Data were collected on vegetative parameters as well as yield components. The data were thereafter subjected to analysis of variance (ANOVA) using Proc GLM procedures (SAS version 9.2) to compute analysis of variance (ANOVA). The least significant difference test (LSD-test) at 5% probability was used for means separation when analysis of variance indicated the presence of significant differences. Results showed that plant density and fertilizer types significantly influenced vegetative parameters as well as yield components. Number of tubers plan^{-1} and average tuber weights significantly decreased with increase in plant density. The highest tuber yield plant^{-1} was obtained at the lowest density (P1=20,000 plants ha^{-1}), while the highest yield ha^{-1} was obtained at the highest density (P4= 50,000 plants ha^{-1}). Poultry manure consistently outperformed other fertilizers types in enhancing vegetative growth parameters as well as yield components. In conclusion, the authors recommend using a higher plant density to maximize yield ha^{-1} and prioritizing poultry manure as it significantly improves vegetative growth and tuber yield.
Key words: Potato, density, mineral and organic fertilizer,

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) a member of Convolvulaceae family (the morning glory) is one of the most widely grown root crops in the world [1]. The crop is widely cultivated for its enlarged edible storage roots which provide high amount of starch to staple diets. Sweet potatoes have multiple uses as it is a regular food and cash crop, used as raw materials and for livestock feed. It is also an important source of income especially in the rural areas. It is an important root crop that provides food to a large segment of the world population, especially in the tropics and subtropics where bulk of this crop is cultivated and consumed. Sweet potato is one of the most economically important crops for addressing global food security and climate change issues, especially under conditions of extensive agriculture, such as those found in developing countries [2].

Despite the numerous potentials uses and benefits of sweet potato in Nigeria, the production of the crop is below the nation's potential. Sweet potato has a yield potential of 20–50 tons per hectare wet weight in the tropics [3]. Farmers in Sub-Sahara Africa produce below 10 tons per hectare wet weight on the average [4], while farmers in Nigeria recorded one of the world's lowest average potato yields of less than 3.1 tons per hectare. In the United States of America and Japan, yields of 22.8 and 21.7 tons per hectare has been recorded respectively [5]. Despite the availability of high-yielding varieties of sweet potato in Nigeria, its yields are mostly limited by progressive declining soil fertility combined with low use or no fertilizers as well as lack of good agronomic practices such as lack of proper weed control, insect pest knowledge, improper use of fertilizer, and sub-optimal plant density [6], Socio-economic and demographic pressures also continue to compete and deprived agricultural sector of arable land leading to continuous cultivation of available land which depletes soil fertility status. Unfortunately, the continuous, and intensive use of limited arable land is expected to produce enough to satisfy the ever-increasing population and raw materials for industries.

In an attempt to achieve this, adoption of many strategies including proper planting density, the use of organic and inorganic inputs is prerequisite to good yield. Planting density is an important factor in regulating yield formation in the crop lifespan. However, the planting density of sweet potatoes is low in most areas of Nigeria at approximately 20,000 plant ha^{-1}. Therefore, increased planting density is a vital cropping measure to realize the maximum sweet potato yield potential [7]. An appropriate planting density is hypothesized to coordinate the relationship between shoot and root development and promote sweet potato storage root formation by stimulating carbohydrate accumulation and limiting lignin biosynthesis, ultimately increasing the storage root number. The use of organic input has potential to sustain crop yield and guarantee environmental safety. Application of organic fertilizer such as animal manure, sawdust, and others, or the combination of organic and inorganic fertilizers, can be an alternative option to reduce the utilization of inorganic fertilizers. Organic fertilizer, compared to inorganic fertilizers, maintain soil quality, increase soil organic matter, as well as improve soil physical and chemical properties through the decomposition of its substances [8]. Organic matter enhances soil nutrients, plant growth regulators, and biodiversity [9]. Hence, aim of this research was to determine the effect of plant density and different fertilizer type on growth and yield of sweet potato variety, Ascertain the appropriate plant density and fertilizer type for the optimum productivity of sweet potato and, determine the effects of plant density and fertilizer type on residual soil chemical properties.

Materials and Methods

Experimental site

Field experiment was conducted in Jos, South local government area of Jos, Plateau State, Nigeria. Located on latitude 09° 55.00" N and longitude 08°53.25" with elevation of 1238m above the sea level. The experimental site is characterized by a humid tropical climate with a mean annual rainfall of 1411 mm and daily temperature of 20.4^{0}C; it lies within the middle belt Agro-ecological zone of Nigeria, and it is now degraded to secondary forest due to continuous cropping

Sweet potato variety, poultry manure, cow dung, NPK and experimental design

UMUSP-3 variety of sweet potato was obtained from Root and Tuber Research Institute Umudike, Abia State Nigeria, while Fertilizer (NPK) was purchased from the Agricultural Development Program (ADP), Dogon, Dutse, Jos North, Plateau State, cow dung was obtained from abattoir, Jos North, Plateau, State while poultry manure was obtained from poultry unit of University of Jos farm. The samples of poultry and cow dung manure were air-dried, crushed through a 2 mm sieve and analyzed following standard laboratory procedures in order to determine its chemical properties. Soil samples were collected from the experimental site prior to the commencement of experiment at 0-20 cm depth with soil auger, about 9-11 sample points were taken from each block, mixed thoroughly to represent a composite sample. One composite soil sample was taken per plot prior-to commencement of the experiment and after the experiment for laboratory analysis. The soil samples were air-dried, pulverized and sieved through a 2 mm sieve. Soil samples were analyzed following the procedures outlined by [10]. Soil pH was determined in 1:2.5 soil: water ratio with a pH meter. Organic carbon was determined by Walkley Black Dichromate Method, Organic carbon was multiplied by 1.724 (The van Bemmelen factor), total N by micro-Kjeldahl method: available P was extracted with Bray – 1 method for acidic soils [11]. Exchangeable bases (K, Ca, Na, Mg) were extracted with 0.1N ammonium acetate, K and Na were read with a flame photometer.

The field were laid out in a 4 × 4 factorial arrangements fitted into Randomized Complete Block design (RCBD) and replicated three times. Each replicate consisted of sixteen ridges each carrying a treatment. The plot treatment consisted of four density (50 x 100 cm (20,000 pph), 40 x 100 cm (25,000 cm), 30 x 100 cm (33,333 pph) and 20 x 100 cm (50,000 pph)) and four fertilizers types (Control 0 t. ha^{-1}, Cow dung 5 t. ha^{-1}, Poultry manure 5 t. ha^{-1} and NPK at 120 kg ha^{-1}). Each ridge was measured 5 × 1.5 m. A total land size of 777 m^2 (37 x 21 m) was marked out for the study. An alley of 0.5 m and 1.0 m respectively was left between plots and blocks to prevent treatment drift to adjacent plots.

Cultural practices

The land used for the experiment had been under continuous Irish potato (*Solanum tuberosum* L.) and wheat (*Triticum aestivum*) cultivation for the past few years, and was occupied by common weeds, including Chromolaena *odorata,* Cyclocarpa *stellaris,* Pennisetum *polystachion* and Imperata *cylindrica*. It was manually stumped and thereafter about 200-250 ml of Roundup Promax (glyphosate) was mixed in 20 l of water and sprayed to the existing vegetation. Fourteen days after glyphosate application the land was ploughed, harrowed and ridged manually. The vine of sweet potato variety (UMUSP-3) was cleaned off dirt and washed under running tap water before cutting into 30 cm lengths of 3-4 nodes and planted manually at one per hole, the spacing were 50 x 100 cm, 40 x 100 cm, 30 x 100 cm and 20 x 100 cm which corresponds to plant densities of 20,000, 25,000, 33,333 and 50,000 plant per hectare. Poultry and cow dung manure was applied in split at the rate of 5 t. ha^{-1}: one half of the rate was incorporated into designated plots and mulch during land preparation for about two weeks for manure equilibration, and the other half four weeks after planting using ring method of application after being pulverized. Similarly, 120 kg ha^{-1} of NPK was applied in split, one half of the rate was applied to designated plots two weeks after planting and the other half at four weeks after planting.

Measurement on vegetative growth parameters

Data were collected at two spots within 1 × 1m quadrant on each plot based on the following parameters;

Vine length: measured from the base of the plant to the tip of the longest vine using a measuring tape.

Vine girth: measured using a Vernier caliper at the midpoint of the vine

Internode length: calculated by measuring the distance between two consecutive nodes along the vine.

Number of Nodes: counted manually along the length of the vine

Leaf Area index: determined using a leaf area meter per plant and dividing by the ground area covered by the plant

Measurements on yield components

At harvest, data were collected on number of tubers per plant, tuber weight and tuber yield. Tuber weight was determined by weighing all harvested tubers within each net plot of 1 x 1 m in kg and divided by the number of plants within the net plot. Tuber Yield was estimated thus: Tuber yield = kg plant^{-1}/1,000.

Statistical analysis.

The data collected were subjected to analysis of variance (ANOVA) using Proc GLM procedures (SAS version 9.2) to compute analysis of variance (ANOVA). The least significant difference test (LSD-test) at 5% probability was used for means separation when analysis of variance indicated the presence of significant differences.

Results and Discussion

Pre-cropped physical and chemical properties of experimental site

The results for pre-cropped soil analysis indicated that the soil was Sandy loam in texture with sand, silt and clay content of 52.8, 29 and 18.2 percent respectively and very strongly acidic in reaction (pH 5.02). Organic carbon and total Nitrogen were seemingly low: 0.88 and 0.09 % respectively. While available phosphorous and calcium were moderate (12ppm and 620 ppm) respectively. Magnesium and sodium were low, while potassium was very high (68 ppm). The cation exchange capacity (CEC) was low (3.12 cmol kg^{-1}) compared to the benchmark set by [12] for Nigerian soils as presented in Table 1. The result on soil analysis agrees with the findings of [13] who reported that high proportion of sand content with low cation exchange capacity, implies that cations would be easily leached, as soil texture determines the degree of retention or leaching of basic cations. The low nutrient levels observed prior to fertilizer application can be attributed to continuous cropping without soil amendments, leading to the depletion of organic carbon, organic matter, total nitrogen, available phosphorus, and exchangeable cations, these findings are in harmony with the findings of [14], who reported that continuous cultivation without adequate soil management practices leads to nutrient depletion and soil degradation. However, the post-harvest soil analyses indicated a tremendous increase of organic matter, organic carbon, Nitrogen content and exchangeable bases at the experimental site with application of poultry manure, which means a better CEC, less soil acidity, and therefore more ability of the soil to supply the important nutrients to sweet potato plants compared to cow dung and NPK fertilizers. Sweet potato as a crop grows best at a soil pH between 5.5 and 6.8 with pH 5.8 - 6.0 being optimum. In this range, N, P, K, Ca and Mg are readily available. This is supported by the results of chemical analysis of the site soil carried out after harvest as they indicated that the levels of total nitrogen and available phosphorus have slightly increased. Post-harvest soil analysis indicated that application of poultry manure improved soil pH from acidic level to neutral showing that poultry manure could be used as liming material in acidic soils. Cattle dung and NPK had no significant effect on the pH of the soil used for the experiment. However, cattle dung and NPK increased in values compare to non-amended plots. Though, many researchers affirmed that cattle dung increases soil pH, this experiment showed that it is not in all cases.

Influence of plant density and fertilizer types on some vegetative parameters of UMUSP-3 Variety of sweet potato in Jos South

The effect of plant density and fertilizer types on vegetative growth parameters of UMUSP-3 variety is presented on Table 3 and Table 4 respectively. The result showed that at all growth stages, plant density had no significant influence on vegetative growth parameters of UMUSP-3 variety. However, on table 4., Evaluation at 5 WAP, and 10 WAP showed that plant density significantly differed among the vegetative parameters. All vegetative parameters except number of nodes showed lower values at lower plant density of P1 and at a wider planting space. Three parameters (vine girth, number leaf m^{-2} and leaf area index) consistently increased in its values with increased in plant density at lower spacing at 10 WAP. Notably, internode length and number of vines were inconsistent, as its values tend to progressively increase as plant spacing become closer and higher plant density up till the third closest spacing and higher density; thereafter, they showed a decline in value with plots having closest spacing and highest density at 10 WAP. Only number of nodes decreased with increase in plant density at 10 WAP

Table 1 Physicochemical properties of the soil prior to and after treatment application

	Pre-Cropped	Post-Cropped		
Properties	Control (0 t ha^{-1})	PM (5 t ha^{-1})	CM (5 t ha^{-1})	NPK (120 kg ha^{-1})
pH in (H_2O)	5.02	7.08	5.35	5.29
Organic Carbon (%)	0.88	1.45	1.12	1.01
Organic matter (%)	0.12	3.58	3.11	3.08
Available phosphorus (ppm)	12	14.02	14.01	13.02
Total Nitrogen (%)	0.09	0.24	0.19	0.12
Ca^{2+} (ppm)	620	633	631	621
Mg^{2+} (ppm)	119	133	118	118
K^{+} (ppm)	68	85	84	85
Na^{2+} (ppm)	1.4	1.59	1.55	1.53
CEC (cmol kg-1)	3.12			
Sand (%)	52.84			
Silt (%)	29			
Clay (%)	18.16			
Textural class	Sandy loam			

PM= Poultry manure, CM= Cattle manure

Table 2: Chemical composition of poultry and cattle manure

Properties	Poultry manure	cattle manure
pH in (H_2O) 1:1	5.65	5.38
Organic Carbon (g kg-1)	34.12	31.08
Total Nitrogen (g kg-1)	2.57	2.06
Available Phosphorous (g kg-1)	19.55	15.22
Potassium (cmolkg-1)	0.71	0.4
Calcium (cmolkg-1)	1.62	1.45
Magnesium (cmolkg-1)	0.59	0.58
Sodium (cmolkg-1)	0.23	0.25
Hydrogen ion (cmolkg^{-1})	0.33	0.42
Aluminum ion (cmolkg^{-1})	0.04	0.07
Heavy metals-lead (mg kg^{-1})	0.01	0.08

The non-significant impact could be due interplant competition for light, water and nutrient resources among the plants. Low density of P2 with wider planting space were associated with higher values for vine length, vine girth and number of nodes, this may be due to unrestricted access to resources and space, which resulted in plants exploiting available nutrients in the soil and the photosynthetic active radiation for growth than plants with higher population densities with lower planting space. However, the increase in number of leaf m^{-2} and LAI with increasing plant density indicates an increase in leaf photosynthetic activity due to closer plant spacing. Since leaf is a photosynthetic organ, changes in number of leaves and LAI would affect crop yield. Both parameters increased with increase in plant density. This result agrees with findings of [15] who reported that increase in number of leaf and leaf area index, leading to better interception of solar radiation, better nutrient assimilation and enhanced photosynthesis that favored sweet potato tuberization. Similarly, this result also corroborates earlier research by [16], who reported higher leaf area index (LA1) at closed spacing and that LAI steadily increased from 9 and 12WAP and declined at 15 WAP due to senescence. Fertilizer types significantly influenced vine length, vine girth, number of nodes, internode length and leaf area index. However, vine girth did not differ at 5 WAP, similarly, number of vines did not differ at all growth stages respectively. Control recorded the minimum values for vegetative parameters at all growth stages compare to cattle manure, poultry manure and NPK. Poultry manure significantly produced high values of vegetative parameters compare to cow dungs and NPK fertilizer. Interaction between plant population density and fertilizer types showed that there was non-significant difference. Poultry manure and cow dugs are natural fertilizers, with poultry manure having higher nitrogen content and other essential plant nutrients, and serves as soil amendments. The increase in values of vegetative growth parameters associated poultry manure application could be possible due to increase in organic matter content and decomposition that may have contributed to higher initial N mobilization compared to NPK fertilizer and non-soil amended plots. The increase most often is comparable to or even higher than what obtained with inorganic fertilizer. In this study the author found out that application of poultry manure alone was significantly better in enhancing growth parameters when compared to cow dung and NPK fertilizer application. The enhancement of growth over the control irrespective of source (organic and/or inorganic) underscores the importance of N contained in both sources. Similarly, the findings of this study show that, application of poultry manure to the soil is likely to be of more beneficial to the incoming crops after the harvest of sweet potato compared with control as indicated by post- harvest soil analysis, poultry manure treatments significantly increased soil Mg showing that poultry manure could be used to correct Mg deficiency. This result agrees with those of [17] and other researchers ([18]; [19]) who confirmed that poultry manure application significantly improved average maize height. Decrease in vegetative parameter associated with NPK fertilizers could be due to rapid mineralization and leaching of nutrients below the root zone of the crop, which could have significantly affected the growth of sweet potato. The author findings are in line with the findings of [20] who reported an increase the vine length, vine girth, number of nodes, internode length and leaf area index of sweet potato with application of poultry manure. However, the author findings are not in harmony with the findings of [21] who reported a significant increase in the vegetative parameters of sweet potato with application of mineral fertilizer.

Table 3: Influence of plant density and fertilizer types on vine length, vine girth, number of vines and number of nodes of UMUSP-3 Variety of sweet potato in Jos South

	Vine length (cm)		Vine girth (cm)		Number of vines		Number of nodes	
Treatment	**5 WAP**	**10 WAP**	**5WAP**	**10 WAP**	**5 WAP**	**10 WAP**	**5 WAP**	**10 WAP**
Plant density (pph)								
P1	82.30	246.66	1.69	2.08	1.08	1.08	28.57	43.44
P2	82.61	263.21	1.58	2.88	1.02	1.02	33.01	47.12
P3	80.11	246.33	1.62	2.87	1.17	1.17	31.67	42.01
P4	76.5	251.8	1.61	2.92	1.09	1.09	29.07	41.21
LSD (0.05)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Fertilizer type								
Control (0 t. ha^{-1})	51.11	160.41	1.41	2.18	1.01	1.01	23.17	35.5
CM (5 t. ha^{-1})	88.21	258.22	1.63	2.98	1.08	1.08	34.17	42.5
PM (5 t. ha^{-1})	105.66	297.55	1.64	3.12	1.08	1.08	33.67	47.26
NPK (120 kg ha^{-1})	75.45	277.31	1.64	2.95	1.17	1.17	30.25	47.7
LSD (0.05)	25.44	43.23	Ns	0.5	Ns	Ns	4.74	6.14
interaction (P x F)	Ns	Ns	Ns	Ns	Ns	Ns	Ns	ns

Ns= non-significant, PPh= plant population per hectare, WAP= weeks after planting, P1= 20,000, P2= 25,000, P3= 33,333, P4= 50,000, CM= Cattle manure, PM= Poultry manure

Table 4: Influence of plant density and fertilizer types on internode lengths and leaf area index of UMUSP-3 Variety of sweet potato in Jos South

	Internode length (cm)		Number of leaves (m^2)		Leaf area index (cm)	
Treatments	5 WAP	10 WAP	5 WAP	10 WAP	5 WAP	10 WAP
Plant density						
P1	2.07	3.93	45	67	3.54	4.43
P2	2.28	4.11	97	111	3.75	5.39
P3	2.74	4.78	103	128	3.37	4.56
P4	2.44	4.66	117	267	3.61	5.76
LSD (0.05)	0.71	Ns	12	45	Ns	0.62
Fertilizer types						
Control	1.74	2.44	88	112	2.57	2.61
CM (5 t. ha^{-1})	3.12	5.69	133	245	4.16	6.10
PM (5 t. ha^{-1})	2.67	5.13	121	268	4.09	5.43
NPK (120 kg ha^{-1})	2.67	4.19	116	232	3.45	3.98
LSD (0.05)	0.72	1.02	21	67	0.54	0.62
Interaction P x F	Ns	Ns	21	33	Ns	NS

Ns= non-significant, PPh= plant population per hectare, WAP= weeks after planting, P1= 20,000, P2= 25,000, P3= 33,333, P4= 50,000, CM= Cattle manure, PM= Poultry manure

Influence of plant density and Fertilizer types on yield and yield components of UMUSP-3 variety of sweet potato

The influence of plant density and fertilizer types on tuber yield and its components is presented on Table 5 and 6 respectively. The result showed that number of tubers plant^{-1} differed significantly among plant density treatments. However, average tuber weight remained statistically similar among plant density treatments. On the average effects, number of tubers plant^{-1} decreased significantly with increase in plant density. The highest number of tubers plant^{-1} was observed with the plant density of P1 (4.17), whereas P4 had the least number of tubers plant^{-1} (1.58). Higher plant densities resulted in fewer but potentially more evenly sized tubers per unit area. Similarly, decrease in yield components observed in the study with an increase in plant density are logical and could be attributed to the increase in competition between plants at higher densities for light, nutrients, water, air, and disruption of the balance of growth regulators among plants. In plots with low densities and showing high tuber weight plant^{-1}, could be due to unrestricted access to such resources might have even prevailed. This research corroborates with the findings of [22], who reported that yield per unit area of sweet potato increases with increase in crop density up to a certain limit, beyond which yield reduces as a result of insufficient environmental resources required for plant growth. Similarly, the findings of this research are in line with those of [23] who reported decrease in some yield components of Low-N tolerant maize varieties which could be due to inter plants competition for nutrients at higher plant density while increase observed in yield components of low-N tolerant maize varieties could be due to genetic make of the variety. It's also corroborating the findings of [24], who reported that lower plant densities improve individual plant performance.

Fertilizer types significantly influenced number of tubers plant^{-1} and average tuber weight. On the average effects plot associated with poultry manure treatment had the highest number of tubers plant^{-1} of (4.30) whereas plots treated with NPK fertilizer had the least number of tubers plant^{-1} of (1.80). similarly, On the average effects plot treated with poultry manure gave the highest tuber weight of (62.60 g) followed by cattle manure application while non-amended plot gave the least tuber weight of (18.00 g). The significant influence of poultry manure on number of tuber plan^{-1} and tuber weight can be attributed to its higher nitrogen content and its ability to improve soil structure, enhance nutrient availability, and increase microbial activities in the soil. The increase in yield components with the application of poultry manure, as opposed to NPK fertilizer, can be attributed to several factors. NPK fertilizers primarily provide three essential nutrients: nitrogen, phosphorus, and potassium. While these nutrients are crucial for plant growth, the narrow focus of NPK fertilizers can lead to imbalanced nutrient availability and deficiencies in other essential micronutrients needed for optimal plant growth. Furthermore, NPK fertilizers do not contribute to improving soil structure or enhancing microbial activity, which are vital for sustained nutrient availability and soil health. This confirms results of other field trials that showed that sweet potato yields were higher and more consistent where organic manure were rather than inorganic inputs were applied [25].

Table 5: Influence of plant density and fertilizer types on the yield components of UMUSP-3 Variety of sweet potato in Jos South

Treatment	Number of tubers plant^{-1}					Average tuber weight (g)				
	Fertilizer types					Fertilizer types				
	Control 0 t ha^{-1}	CM 5 t. ha^{-1}	PM 5 t. ha^{-1}	NPK 120 kg	Mean	Control 0 t ha^{-1}	CM 5 t. ha^{-1}	PM 5 t. ha^{-1}	NPK 120 kg	Mean
Plant density (pph)										
P1	2.00	5.00	6.70	3.00	4.17	7.40	33.40	63.70	28.60	33.30
P2	1.00	2.00	5.00	1.30	2.33	18.40	50.70	64.90	44.70	44.70
P3	4.00	3.00	4.00	1.70	3.17	21.90	59.80	44.80	19.20	36.40
P4	1.00	3.00	1.30	1.30	1.58	24.40	53.20	77.30	31.50	40.60
Mean	2.00	3.00	4.30	1.80	2.81	18.00	49.20	62.60	31.00	40.20
LSD (0.05) plant density					1.15					Ns
LSD (0.05) Fertilizer type					1.15					14.78
LSD (0.05) density x fertilizer type					2.31					Ns

Ns= non-significant, PPh= plant population per hectare, WAP= weeks after planting, P1= 20,000, P2= 25,000, P3= 33,333, P4= 50,000, CM= Cattle manure, PM= Poultry manure

Table 6: Influence of plant density and fertilizer types on the yield of UMUSP-3 Variety of sweet potato in Jos South

Treatment	Tuber yield plant^{-1} (g)					Tuber yield per hectare (t. ha^{-1})				
	Fertilizer types					Fertilizer types				
	Control 0 t. ha^{-1}	CM 5 t. ha^{-1}	PM 5 t. ha^{-1}	NPK 120 kg ha^{-1}	Mean	Control 0 t ha^{-1}	CM 5 t. ha^{-1}	PM 5 t. ha^{-1}	NPK 120 kg ha^{-1}	Mean
Plant density (pph)										
P1	98.80	645.20	1453.60	330.40	632.00	3.22	20.93	47.11	10.71	20.49
P2	134.80	441.20	1392.40	311.20	569.90	6.44	21.42	67.69	15.12	27.67
P3	310.00	707.20	749.20	195.60	490.50	20.09	45.85	48.58	12.67	31.80
P4	190.40	560.00	458.00	191.20	349.90	18.55	54.46	44.52	18.55	34.02
Mean	183.50	588.40	1013.30	257.10	510.56	12.07	35.67	51.98	14.26	28.50
LSD (0.05) plant density					67.31					3.85
LSD (0.05) Fertilizer type					93.33					3.85
LSD (0.05) density x fertilizer type					114.6					3.71

Ns= non-significant, PPh= plant population per hectare, WAP= weeks after planting, P1= 20,000, P2= 25,000, P3= 33,333, P4= 50,000, CM= Cattle manure, PM= Poultry manure

Influence of plant density and Fertilizer types on yield of UMUSP-3 variety of sweet potato

Plant density and fertilizer types significantly influenced tuber yield plant^{-1} and yield ha^{-1}, there was a decrease in tuber yield plant^{-1} (from 632.00 to 349.00) with increase in plant density of P1 to P4, lower plant density resulted in a commensurate increase in tuber yield plant^{-1} owing to optimal utilization of nutrient by relative lower number of plants. This could, also, be due to reduced competition, improved light penetration, and enhanced root development among others. The author findings are in tandem with [26] who reported that maximum yields are obtained at a closer density which means lower plant densities due to reduced competition and better resource availability. The enhanced growth conditions at lower densities lead to more productive plants showing significantly higher yields compared to higher plant densities. Similarly, these findings agree with [27] who reported that availability of space had effect on number of tubers formed. The greater the space, the higher the number of tubers formed.

Fertilizer types significantly influenced tuber yield plant^{-1}, with the highest yields observed in plots treated with poultry manure, followed by cow dung, and the lowest yields in plots without amended inputs. This significant increase in yield plant^{-1} with organic fertilizers (poultry manure) can be attributed to several factors such as nutrient availability, soil Structure, fertility and enhanced microbial activity. These results agree with the findings of [28], who also reported increased yield plant^{-1} with the application of poultry manure due to its higher nutrient availability and improved soil conditions. [29] confirmed that organic fertilizers enhance tuber yield more effectively than inorganic ones, likely due to the sustained release of nutrients and improvement in soil organic matter. The authors findings also support the conclusions of [30], who observed increased sweet potato yields with the use of poultry manure, attributing it to better soil physical properties and enhanced nutrient uptake. On the other hand, these findings contrast with the results of [31], who found that mineral fertilizers at high plant densities could also result in high yields plant^{-1}, indicating the effectiveness of fertilizer types can vary with different crop management practices.

Tuber yields ha^{-1} differed significantly among the plant density treatments. On the average, tuber yield ha^{-1} increased (from 20.09 to 34.02 t. ha^{-1}) with an increase in plant density (from P1 to P4). The increase in tuber yield ha^{-1} with higher plant densities can be attributed to more efficient use of available land and resources, despite the lower yield per individual plant. The author's observation agrees with the findings of [32], who reported that increased plant density leads to higher overall yield ha^{-1} due to more efficient land use and resource optimization. Similarly, the author findings align with the results of [33], who found that optimal plant density combined with organic fertilizer application significantly boosts yield ha^{-1} by improving soil fertility and plant health. However, these results contrast with the findings of [34], who noted that mineral fertilizers at high plant densities could also result in high yields per hectare. The variation in findings might be due to differences in soil type, climate, and crop management practices, indicating the need for site-specific fertilizer and density management strategies. This research showed that higher plant density increases the total yield ha^{-1} but decreases the yield plant^{-1} in sweet potato. This result is in tandem with the findings of [35] who reported that with increasing plant density, the yield of sweet potato increased. These findings are consistent with previous research that suggests organic fertilizers improve tuber yield by enhancing soil fertility and structure [36]. This trend underscores the need for balancing plant density and fertilizer type to optimize yield both plant^{-1} and ha^{-1}. These results align with the findings of [37], who emphasized the importance of optimizing plant density and fertilization for maximum yield. The yield of 34.02 t. ha^{-1} obtained at P4 densities ha^{-1} is in conformity with [38] who submitted that high yielding potato varieties could produce up to 50 t ha^{-1}. This was why [39] stressed that planting density in sweet potato is a major factor that influences growth and yield. [40] reported also, that the fortune of any crop could be improved through the adoption of appropriate plant population.

The highest yields of (51.98 t. ha^{-1}) was observed in plots treated with poultry manure, followed by cow dung (35.67 t. ha^{-1}), and the lowest yield (12.07 t. ha^{-1}) in plots without amended inputs. The reasons for this are similar to those for yield plant^{-1} but also include; The enhanced nutrient availability and improved soil conditions provided by organic fertilizers result in more vigorous plant growth. This leads to more productive plants per unit area, contributing to higher overall yields ha^{-1}. Organic fertilizers improve soil moisture retention and reduce nutrient leaching, ensuring that plants have access to the necessary resources throughout the growing season. This efficiency is particularly beneficial in high-density planting systems where competition for resources is intense. These observations align with the findings of [41] who reported that increased plant density combined with organic fertilizer (poultry manure) application leads to higher overall yield ha^{-1} due to more efficient land use and resource optimization. [42] also found that optimal plant density combined with organic fertilizer application significantly boosts yield ha^{-1} by improving soil fertility and plant health. Similarly, the findings of this study agree with those of [43], who reported that higher plant density increases the total yield per hectare, but decreases the yield plant^{-1} in sweet potato.

Conclusion

The study's findings suggest that optimal plant density combined with the application of organic fertilizers, particularly poultry manure, can significantly improve the growth and yield of sweet potatoes. These results have practical implications for sweet potato farmers in Jos South, Plateau State, who aim to maximize yield while maintaining soil health. Farmers are recommended to adopt plant densities of (50,000 plants ha^{-1}) and incorporate organic fertilizers to achieve the best balance between growth and yield. The long-term benefits of organic fertilization on soil properties should be considered in developing sustainable farming practices.

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