NIGERIAN JOURNAL OF CROP SCIENCE
Volume 9 N0 1 January 2024 pp 11 - 20
ISSN – 2350 -2487

IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON DRY MATTER AND ROOT YIELD QUALITY OF SWEETPOTATO IN UMUDIKE, SOUTHEAST NIGERIA

Emmanuel U. Mbah[1*] and Chinedu J. Agu[2]

[1]Department of Agronomy, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

[2]Sweetpotato Programme, National Root Crops Research Institute, Umudike, AbiaState, Nigeria.e-mail:agujohn19@gmail.com
Corresponding author: e-mail: emmaukmbah@gmail.com

ABSTRACT
Information on the effect of integrated nutrient management (INM)on sweetpotato(Ipomoea batatas (L.) Lam) in the humid fringes of southeast Nigeria is inadequate. Therefore, a trial was conducted at National Root Crops Research Institute, Umudike, Nigeria in 2019 and 2020 to assess shoot dry matter, storage root yield and quality responses of sweetpotato to INM. The treatments, laid out in a randomized complete block design with three replications. comprised of all additives of N:P:K (15:15:15), poultry manure (PM) and rice husk dust (RHD) as well as individual application of each. The results indicated that N:P:K+PM significantly ($P<0.05$) gave the highest shoot dry matter, crop growth rate, relative growth rate, β-carotene yield, and starch content in both years compared with the other treatments. The application of N:P:K+PM gave the highest root yields in both years compared to other INM tested but N:P:K+PM+RHD exhibited the highest crude protein and fat in both years. The application of N:P:K+PM indicated high proximate composition of the tested variables. The root yield sequence of the INM was in this order: N:P:K+PM >N:P:K >N:P:K+RHD > PM+RHD>N:P:K+PM+RHD>PM > RHD > No INM in 2019 while in 2020 the order was: N:P:K+ PM >N:P:K > PM+RHD > N:P:K+RHD> PM >N:P:K+PM+RHD > RHD > No INM. The differences in sequence suggested that INM contributed positively to root yield and quality. The application of N:P:K+PM fertilizer was adjudged the most appropriate INM forsweetpotato, hence farmers in the ecoregion can adopt it.

Keywords:β-carotene, crop growth rate, inter-relationship, mineral, proximate.

INTRODUCTION
Sweet potato [*Ipomoea batatas* (L.) Lam] is a very important food root crop in the World though highly under-valued because of its essence as a substitute food crop in most developing countries (FAO, 2016). The crop is a veritable source of carbohydrate, proteins, vitamins, minerals and valuable cash per unit land (Magagula *et al.,* 2010). More so, it is regarded as for its nutritional and industrial importance as well as food security crop in most developing countries of Africa, Asia and Latin America.In the humid tropics, sweet potato which is a heavy feeder that exploits a great volume of soil for nutrients and water is planted across a wide range of farming systems (Mwanga *et al*., 2001; Onunka*et al*., 2012; Szarvas*et al*., 2019). Studies have shown that the yield of sweetpotato in the humid tropics is low due to soil nutrient exhaustion, inadequate organic matter, continuous cropping and soil degradation resulting in poor soil fertility(Mukhtar, 2010; Egbe *et al*., 2012; Kookana*et al.,* 2013). The application of integrated nutrient management (INM), which implies the combined use of organic and mineral fertilizers in crop (sweetpotato) production not only improves the structure and fertility of the soil but also encourages water and nutrient retention for easy absorption by the growing crop thereby reducing continuous decline of soil nutrients (Mba and Onweremadu,2009; Varela *et al.,* 2013; Lu *et al*., 2014). More so, according to Sui *et al.* (2016) the efficacy of INM depends on factors such as type of organic material, application rate, feed stock used, type of crop and soil. Studies have shown that sweetpotato requires high nutrient demand, especially potassium (K) because leaves, vines, stems and roots

usually remove substantial quantities of K from the soil (Degras, 2003; Dapaah*et al*., 2004). Root yield and quality of sweetpotato can be enhanced if it receives balanced fertilization management in the form of INM (Patricia and Bansal, 1999). However, there is dearth of information on the effect of INM on growth, yield and nutrient quality of sweetpotatounder tropical conditions. Therefore, the objectives of the study were to evaluate shoot dry matter content, storage root yield and quality response of sweetpotato to INM in Umudike, Southeast Nigeria.

MATERIALS AND METHODS

Field trials were conducted in 2019 and 2020 cropping seasons at National Root Crops Research Institute, Umudike, which is located in the humid tropics along longitude 07° 33′ E, latitude 05° 29′ N and at an altitude of 122 m above sea level in Nigeria. The experimental area is characterized by a mean total rainfall of about 2177 mm per annum that is bi-modal in pattern with maximum mean air temperature of about 31 °C. The predominant vegetation is typical rainforest (Nest, 1991). The trial site was cleared, ploughed and one metre ridges made. Pre-planting soil samples were collected at the depth of 0 to 20 cm and analyzed for soil physico-chemical properties such as pH, soil organic carbon and organic matter, total nitrogen, available phosphorus and exchangeable bases following standard analytical procedure as shown in Table 2. The prepared field was marked and pre-emergence herbicides *Premextra* and *Touch-down* were applied at the rate of 250 ML^{-1} 15 Lof water and applied four days before planting the sweetpotato vines. The trial was laid out in a randomized complete block design with three replications. The integrated nutrient management (INM) consisted of poultry manure (PM) at 10 t ha^{-1}, rice husk dust (RHD) at 10 t ha^{-1}, N:P:K fertilizer 15:15.15 at 400 kg ha^{-1}, PM at 5 t ha^{-1} + N:P:K fertilizer at 200 kg ha^{-1}, PM at 5 t ha^{-1} + RHD at 5 t ha^{-1}, RHD at 5 t ha^{-1} + N:P:K at 200 kg ha^{-1}, PM at 3.3 t ha^{-1} + RHD at 3.3 t ha^{-1} + N:P:K at 133.3 kg ha^{-1}, No INM application (Control). The organic matter based treatments were incorporated into their respective experimental plots seven days before planting while N:P:K 15:15:15 fertilizer was applied two weeks after vine sprouting.

Rice husk dust was sourced from a rice milling plant while the poultry manure was obtained from a dip-litter poultry farm. The sweet potato vines (*Umuspo* 1, orange flesh) were planted into trial plots of 3 x 3 m(9m ^{2}) at the spacing of 30 x 100 cm to give a plant population of 33,333 plants ha^{-1}. Clean vines containing five nodes were planted on the crest of each ridge at an angle of 45^{o} with two nodes inserted into the soil.At four and eight weeks after planting, three samples of sweetpotato plants were randomly collected from the inner rows of each plot and subjected to oven-drying at 70 °C in an electric oven (model OV-420), Sweden until a constant weight was achieved with the aid of a sensitive weighing balance (Mettler, Model P. 1200). The dried samples were weighed and re-weighed for confirmation. The weight values obtained from the sweetpotato dry shoot were used to calculate some biometric growthanalysi such as:

[i] Crop growth rate (CGR), which measures the rate of dry matter production per unit land per unit time as described by (Watson, 1952) with the formula:

CGR = $W_2 – W_1$ / P ($T_2 – T_1$), where, W_1 and W_2 = biomass yield at harvest at times T_1 and T_2,P = ground area on which W_1 and W_2 have been estimated.[ii] Relative growth rate (RGR**)** of the sampled shoot dry weight was determined according to the procedure described by Radford (1967) with the formula:RGR = $Log_e W_2 – Log_e W_1 / Log_e W_1 (T_2 – T_1)$, (g g^{-1} day^{-1}), where, W_1 and W_2 = biomass yield at harvest at times T_1 and T_2. At harvest, the data on number and weight of fresh roots from each plot were obtained and fresh root yield (t ha^{-1}) was calculated.

Proximate analysis - Nutritional composition

Crude protein of the sweetpotato sample was determined using the Kjedahl method as outlined by Chang (2003). A known quantity (0.5 g) of sweetpotato root was scooped out and 20 mLs of concentrated H_2SO_4 was added to the sample and then introduced into the digestion flask. A Kjedahl catalyst (Selenium tablet) was added to the sample and heated under a fume cupboard for eight hours until a clear solution was obtained (digest). The cooled digest was transferred into 100 mL volumetric flask and made up to the mark with distilled water.

Then 10mLs of the digest was made alkaline with 20 mLs of sodium hydroxide (NaOH) (20 %) solution and distilled in kjeldahl distillation apparatus. Thereafter, 20 mLs of 4 % Boric acid were pipetted into a conical flask and five drops of methyl red was added to the flask as indicator and the sample was diluted with 75 mL distilled water. The distillates were collected and titrated against 0.02 N ethylenediaminetetraacetic acid (EDTA). The steam exit of the distillatory was closed and the change of color of boric acid solution from green to deep red end point was timed. The mixture was distilled for 15 minutes. A reagent blank was also digested, distilled and titrated. The total N_2 in the sample was determined and the protein content calculated with the formula:

[i] % Protein = % N_2 × conversion factor (6.25), where,

% N_2 = (100 / W × N × 14/1000 × V_t/ V_a) T - B

W = Weight of sweetpotato scoop (0.5 g),

N = Normality of the titrant (0.02 N H_2SO_4),

V_t = Total digest volume (100 mLs),

V_a =Volume of digest analyzed (10 mLs),

T = Titre value,

B = Blank titre value.

The fat content of the sweetpotato samples was determined using solvent extraction in a Soxhlet apparatus as described by Onwuka (2005). The process was achieved by collecting 2 mLs of the sweetpotato sample which was then wrapped in a filter paper and placed in a Soxhlet reflux flask that was connected to a condenser on the upper side and to a weighed oil extraction flask full with 200 mLs of petroleum ether. The ether was brought to its boiling point, the vapour condensed into the reflux flask immersing the samples completely for extraction to take place on filling up the reflux flask siphons over carrying the oil extract back to the boiling solvent in the flask. The process of boiling, condensation, and reflux was allowed to go on for four hours before the deffated samples were removed. The oil extract in the flux was dried in the oven at 60 ˚C for thirty minutes and then weighed.

[ii] $\% \text{ Fat content} = \frac{\text{Weight of fat}}{\text{Weight of sample}} \text{ x } 100.$

The carbohydrate contents of the sweetpotao root samples was calculated with the formula:

[iii] % Carbohydrate = 100 - % (protein + fat + fibre + ash + moisture content) (James, 1995).

The energy value was estimated using Atwater factors as described by Onwuka (2005). The energy value was calculated by multiplying the proportion of protein, fat and carbohydrate by their respective physiological fuel value of 4, 9, and 4 kcal g^{-1}, respectively and taking the sum of their products. The energy value was calculated thus:

[iv] Energy value (EV) = (% Crude protein × 4) + (% Crude fat × 9) + (% Carbohydrate × 4).

β-carotene content was determined using thespectrophotometric method as outlined by Onwuka (2005). Sweetpotato root samples (5 mLs) were separately dissolved in 30 mLs of absolute alcohol (ethanol) and 3 mLs of 5 % Potassium hydroxide (K_2OH) was added to it. The mixture was boiled under reflux for 30 minutes and cooled rapidly with running water and filtered. Distilled water (30 mLs) was added and the mixture transferred into a separating funnel after which three portions of 50 mLs of the ether was used to wash the mixture. The lower layer was discarded and the upper layer washed with 50 mLs of distilled water. The extract was evaporated to dryness and dissolved in 10 mLs of Isoprophyl alcohol and its absorbance was measured at 325 nm. β-carotene content of the sample was then calculated as follows:

β-carotene (mg 100 g^{-1}) = $\frac{100}{w} \times \frac{au}{as} \times c$, where,

au = absorbance of test sample

as = absorbance of standard solute

c = concentration of the test sample

w = weight of sample

Starch extraction from sweetpotato roots was achieved through grating with water and sieves used to separatethestarch slurry from residual mass. The starch is recovered by decantation or centrifugation. The starch content was calculated following procedure by Moorthy (1991) as follows: Starch content = $\frac{W_3 - W_2}{W_1} \ X \ 100$, where,

W_1 = weight of sample.

W_2 = weight of empty beaker

W_3 = weight of starch

Mineral analysis

Phosphorus content of the sweetpotatosamples was determined by the vanado-molybdate (yellow) spectrometry method (James, 1995). The test solution (5 mLs) was pipetted into 50 mLs graduated flask. Then, 10 mLs of molybdate mixture was added and diluted to mark with distilled water. It was then allowed to stand for 30 minutes for colour development at room temperature. The absorbance was measured in Jenway electronic spectrophotometer at wave length at 600 nm against a blank at zero. A curve relating absorbance to mg phosphorus present was plotted. Using the phosphorus standard solution, and following the same procedure for the sample, a standard curve was plotted to determine the concentration of phosphorus in the sample.

Phosphorus content was given by the formula:

P (mg / 100 g) = $((100 / W) \times (A_u / A_s) \times C \times (V_f / V_a))$, where,

W = Weight of sample analysed,

A_u = Absorbance of the test sample,

A_s = Absorbance of standard solution,

V_f = Total volume of filtrate,

V_a = Volume of filtrate analysed,

C = Concentration of the standard in mg / mL.

Potassium was determined by flame photometry method (James, 1995). Potassium standard was prepared. The standard solution was used to calibrate the instrument read out. The meter reading was at 100 % E (emission) to aspire the top concentration of the standards. The percentage emission of all the intermediate standard curves were plotted on linear graph paper with these readings. The sweetpotato sample solution was aspired on the instrument and the readings (% E) were recorded. The concentration of the element in the sample solution was read from the standard curve and potassium calculated as follows:

$\% \text{ Potassium} = \frac{\text{ppm X 100 X DF}}{1000}$, where,

Df = Dilution factor

ppm = parts per million.

Calcium content of the sweetpotatosamples was determined by the complexiometric titration method of Onwuka (2005). Twenty milliliters (20 mLs) of the sweetpotato extract was dispersed into conical flask and treated with pinches of the masking agents (Hydroxylamine hydrochloride, sodium cyanide and sodium ferrocyanide). The flask was shaken and the mixture dissolved. Twenty milliliters of ammonia buffer were added to it to raise the pH to 10.00. The mixture was titrated against 0.02 N EDTA solution using Erichrome Black T as indicator. A reagent blank was also titrated and titration in each case was done from deep red to a permanent blue end point. The titration value represents both Ca^{2+} and Mg^{2+} in the test sample. The analysis was repeated to determine Ca^{2+} alone in the test samples. Titration of calcium alone was done in similarity with the above titration, 10 % NaOH was used in place of ammonia buffer and solechrome dark blue indicator in place of Erichrome black T. Total calcium content was calculated separately using the following formula: $\text{Ca (mg/mg)} = \frac{100}{W} \times \frac{T-B\ (N \times Ca)}{Va} \times \frac{Vf}{1}$, where

W = Weight of sample
T = Titre value of sample
B = Titre value of blank
Ca = Calcium equivalence
Mg = Magnesium equivalence
Va = Volume of extract titrated
Vf = Total volume of extract
N = Normality of titrant (0.02 N EDTA).

Statistical Procedures

The variables measured were subjected to analysis of variance using the Genstat Discovery statistical package for windows to estimate integrated nutrient management (INM) effects on the crop characters assessed with INM as a fixed variable in each year analysis. The significant treatment means were separated using F-tests (LSD) at $P \leq 0.05$ according Obi (2002). Pearson correlation coefficients of yield to other variables to determine the inter-relationships amongst them was calculated using SPSS 25 statistical software for windows and the significance between the variables tested by referring to the standard table (Snedecor and Cochran, 1980) with n - 2 degrees of freedom, where n is the total number of observations.

RESULTS

Agro-meteorological results (Figure 1) indicated that the experimental area experienced a mean total rainfall of about 3060.4 and 2286.9 mm in 2019 and 2020 cropping seasons, respectively. The average maximum monthly air temperature was 31.7 in 2019 and 32.7 in 2020. The physico-chemical laboratory analysis of the experimental soil (Table 1) showed that the soil was texturally sandy loam with a soil pH that was moderately acidic while the soil nutrient composition oscillated from low to moderate.The chemical analysis of poultry manure and rice husk dust used for the trial were carried out Integrated nutrient management (INM) significantly affected shoot dry weight of sweetpotato only at 4 weeks after planting (WAP) in 2019 and at the two sampled ages (4 and 8 WAP) in 2020 cropping seasons (Table 3).The application of N:P:K 15:15:15 + poultry manure gave the highest SDW compared with the other treatments at the sampled ages that were significant in 2019 and 2020 cropping seasons.Furthermore, INM significantly affected crop growth rate (CGR) and relative growth rate (RGR) in both cropping seasons. In 2019 cropping season, the highest CGR and RGR values were recorded under the application of N:P:K 15:15:15+ poultry manure compared to the other integrated nutrients used in the study, and the trend was the same in 2020 cropping season.

The results from the analyses of variance (Table 4) indicated that INM significantly ($P<0.05$) affected carotene and starch contents in storage roots of sweetpotato as well as number of roots plot^{-1} and fresh storage root yield of the crop in both cropping seasons. Among the variables (carotene and starch contents) studied, the application of N:P:K + poultry manure (PM) gave the highest carotene and starch yields (781.04 µmg 100 g^{-1} sample and 16.24 %), respectively in 2019 and (811.56 µmg 100 g^{-1} sample and 17.84 %), respectively in 2020 cropping seasons. Furthermore, in 2019 cropping season, the application of N:P:K + rice husk dust (RHD) gave the highest number of roots plot^{-1} compared to the other nutrient treatments but the trend was not the same in both years. However, the highest storage root yields were recorded under the application of N:P:K + PM INM compared to the other treatments, and which were higher by 65.0 and 65.5 per cent relative to zero INM (control), respectively in 2019 and 2020 cropping seasons.

In both cropping seasons, INM exhibited highly significant ($P<0.001$) effect on mineralcomposition (phosphorus, potassium and calcium) in storage root of sweetpotato (Table 5).The application of N:P:K + PM exhibited the highest amount of phosphorus and potassium uptake compared to the other nutritenttreaments in 2019 cropping seasons. However,potassium uptake compared to the other nutriten ttreaments in 2019 cropping seasons. However, the trend was not the same in 2020 while the application of N:P:K + RHD increased the amount of calcium uptake in the root of sweetpotato more than in the other treatments in both cropping seasons.

The results from analyses of variance on proximate composition of fresh storage roots of sweetpotato in 2019 and 2020 cropping (Table 6) exhibited significant ($P<0.05$) effect on crude protein, fat, carbohydrate and energy value.The application of N:P:K + PM + RHD in both cropping seasons gave the highest crude protein and energy value while highest percentage fat and carbohydrate were recorded under N:P:K + PM INM in both cropping seasons except fat in 2020 that was highest under N:P:K + PM + RHD INM application.The correlation analysis (Table 7) indicated non-significant correlation between fresh storage root yield and the variables tested in 2019 cropping season. However, in 2020 cropping season, fresh storage root yield exhibited positive and significant correlation with number of storage roots plot^{-1}. The other variables exhibited various degrees of positive and negative significant variations amongst themselves.

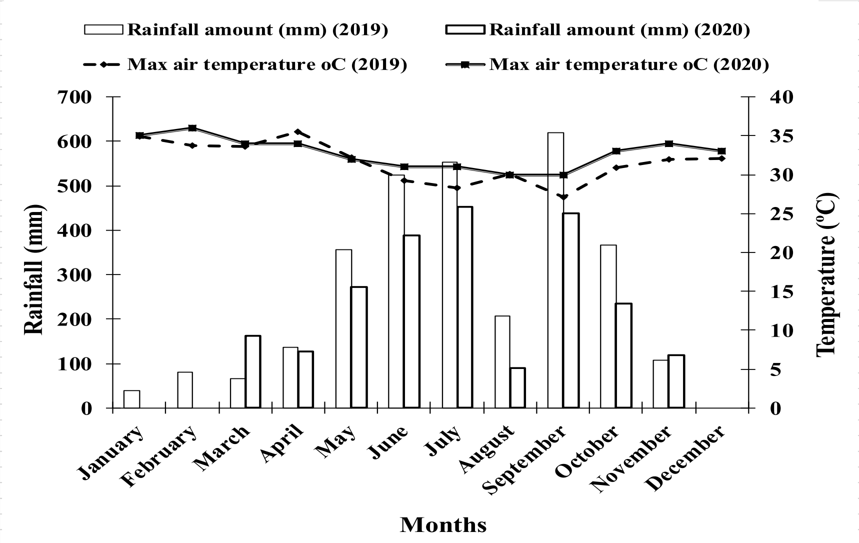

Fig. 1: Meteorological data of the experimental site in 2019 and 2020 cropping season Sourced: Agro-meteorological Unit, National Root Crops Research Institute, Umudike, Nigeria.

Table 1.Physico–chemical properties of the soil (0-20 cm) of the experimental site,Umudike, Nigeria in 2019 and 2020 cropping seasons

Chemical characteristics	2019 Value	2020 Value	Analytical methods
pH (1:2.50; Soil:Water ratio)	4.60	4.50	Determined using a suspension of soil and distilled water. After stirring for 30 min, the pH value was read using an electronic glass electrode pH meter, Jenway model 3510 (Jackson, 1973).
Organic Carbon (%)	0.19	0.19	Improved chromic acid digestion and spectrophotometric method (Nelson and Sommers, 1982). Wet oxidation method through chromic acid digestion (Walkley and Black, 1934).
Organic Matter (%)	23.10	25.40	Percentage organic matter was derived by multiplying % organic carbon by Broadbent's factor of 1.72 (Nelson and Sommers, 1982).
Total N (%)	0.13	0.95	Semi-micro kjedahl digestion method using sulphuric acid and copper sulphate and sodium sulphate catalyst mixture (Bremner, 1996).
Available P (mg kg^{-1})	13.78	17.16	Molybdenum blue colorimetry method (Olsen and Sommers, 1982).
Exchangeable Base (cmol (+) kg^{-1})			
K^{2+}	3.60	3.20	Ammonium acetate extraction method and read on flame photometer using FP 8800 model, with acetylene of propane burner (Olsen and Sommers, 1982).
Na^{+}	0.15	0.15	
Ca^{2+}	1.60	7.20	Ammonium acetate extraction method and determined using ethylenediaminetetraacetic acid (EDTA) titration method with the model 8089-A2 (Olsen and Sommers, 1982).
Effective CEC (cmol (+) kg^{-1})	6.90	6.17	Soil exchangeable acidity (H+) was determined by titration of normal KCI-extracted acidity against 0.05N sodium hydroxide. Effective cation exchange capacity (ECEC) was obtained by a summation of the exchangeable cations (Na, K, Mg, Ca) and exchangeable acidity.
Base saturation (%)	81.45	77.95	Base saturation was obtained by calculation as the percentage of the CEC occupied by the basic cations Na^{+}, K^{2+}, Mg^{2+}, Ca^{2+}; % BS = $[(Na^{+} + K^{2+} + Mg^{2+} + Ca^{2+}) / CEC] \times 100$.
Physical characteristics (%)			
Sand	75.20	73.20	
Silt	18.40	20.40	Hydrometer method (Bouyoucos, 1962).
Clay	6.40	6.40	
Textural class	Sandy loam		Characterized as ultisol (Paleustalt) (USDA Classification).

DISCUSSION

The integrative use of integrated nutrient management (INM) or combined application of organic and inorganic fertilizers, which released optimum amount of nutrients progressively through mineralization substantially improved sweetpotato phenology (shoot dry weight, crop growth rate and relative growth rate) and yield parameters. The findings corroborate similar results by Balemi (2012) in the highlands of Ethiopia as well as Mukhtar*et al.* (2010) and Esan *et al.* (2021) in the rainforest zone of southern Nigeria who submitted that combined treatmentof organic and inorganic manures remarkably increased the production performance of sweetpotato. Furthermore, the application of N:P:K + poultry manure appreciably increasedyield components, such as weight of roots plot^{-1} and storage root yield ha^{-1} as well as β-carotene and starch content compared to other treatments in the two cropping seasons. The findings were in consonance with the previous works of Nwaigwe*et al.* (2017) and Nunes *et al*. (2020) that INM markedly increased the storage root yield of sweetpotato due to better uptake of nutrients, increased shoot dry weight, crop growth rate and relative growth rate. The increase in storage root yield might be due to better availability of the essential elements (nitrogen, phosphorus and potassium) in poultry manure compared to the other organic materials applied to compliment the inorganic fertilizer (N:P:K-15:15:15) used in the study. The present results were corroborated by previous studies by Bhagsari and Ashley (1990), Igbokwe *et al.* (2005) and Kathabwalika*et al*. (2013) who reported significant increases in yield components with the application of organic manure. Furthermore, the results from the study were also in line with previous findings by Patricia and Bansal (1999), Mukhtar *et al*. (2010) and Onunka*et al*. (2012) who also reported that application of poultry manure increased the release of major nutrients, which in turn enhanced not only growth performance but also storage root yield and yield components of sweetpotato. The differences in storage root yield between different treatments can be explained by differences in their shoot dry weight and crop growth rate. The findings were in line with similar works by Kubota *et al*. (1992) in Japan Nedunchezhiyan and Srinivasulu (2004) in India, Mbah and Eke-Okoro (2015)in Nigeria as well as Souza *et al*. (2016) in Ethiopia, which surmised that shoot dry weight can be affected by activated physiological increase in sweetpotato growth due to increased absorption of dissolved and readily available plant nutrients from the applied organic manure.

Conjunctive use of N:P:K + poultry manure significantly increased potassium, fat and carbohydrate, however, the application of N:P:K + poultry manure + rice husk dust outperformed the other treatments in crude protein content and energy value. The increase inprotein content in sweetpotato roots can be ascribed to better availability of nitrogen. The present results are consistent with previous results by Low*et al.* (2009), Donado-Pestana*et al.*(2012) and Islam *et al*. (2016), who reported from various studies significant effect of combined organic manure and inorganic fertilizer on β-carotene and starch content of storage root of sweetpotato,.

Table 2.Chemical analysis of the poultry manure and rice husk dust used in the study

Mineral elements (%)	Poultry manure (PM)		Rice husk dust (RHD)	
	2019	2020	2019	2020
Nitrogen	3.01	2.87	1.96	2.07
Phosporus	20.80	21.08	19.90	19.45
Potassium	13.03	13.35	2.23	2.13
Organic carbon	12.16	12.92	8.74	9.50
Organic matter	20.92	22.22	15.03	16.34
Calcium	5.81	5.61	4.11	3.81
Magnesium	0.55	0.67	0.43	0.55
Sodium	2.18	2.08	1.09	1.20
pH	7.4	6.9	9.6	9.1

Table 3. Effect of integrated nutrient management on shoot dry weight, crop growth rate (CGR), and relative growth rate (RGR) of sweet potato in 2019 and 2020 cropping seasons

Treatments	Shoot dry weight (g) 4 WAP	Shoot dry weight (g) 8 WAP	Crop growth rate (g m^{-2} day^{-1})	Relative growth rate (g g^{-1} day^{-1})	Shoot dry weight (g) 4 WAP	Shoot dry weight (g) 8 WAP	Crop growth rate (g m^{-2} day^{-1})	Relative growth rate (g g^{-1} day^{-1})
	2019				2020			
No manure (Control)	8.0	56.7	0.54	0.10	5.27	11.50	0.23	0.01
N.P.K	15.5	63.0	0.52	0.09	6.75	14.40	0.77	0.04
Poultry manure (PM)	26.2	63.0	0.32	0.04	8.40	15.12	0.16	0.01
Rice husk dust (RHD)	10.7	58.0	0.52	0.21	10.93	11.90	0.09	0.01
N:P:K + PM`	33.6	97.0	0.92	0.26	13.80	23.82	1.70	0.39
N:P:K + RHD	13.4	96.7	0.78	0.21	7.07	10.70	0.62	0.08
PM+RHD	20.1	84.3	0.71	0.12	7.50	11.31	0.39	0.02
N:P:K + PM + RHD	25.7	85.3	0.66	0.08	6.60	11.00	0.44	0.02
$LSD_{(0.05)}$	17.51	ns	0.28	0.09	0.45	0.10	0.02	0.01

Table: 4. Effect of integrated nutrient management on carotene content, starch content and yield attributes of sweet potato in 2019 and 2020 cropping seasons

Treatments	Carotene content (µmg 100 g^{-1} sample)	Starch content (%)	Number of roots $plot^{-1}$	Weight of roots net $plot^{-1}$ (kg)	Fresh root yield (t ha^{-1})	Carotene (µmg 100 g^{-1} sample)	Starch (%)	Number of roots $plot^{-1}$	Weight of roots net $plot^{-1}$ (kg)	Fresh root yield (t ha^{-1})
			2019					**2020**		
No manure	489.39	10.55	18.00	1.20	6.80	506.16	14.19	17.0	1.37	7.77
N.P.K	516.24	12.72	14.67	2.00	16.96	591.34	16.08	19.00	2.33	15.54
Poultry Manure (PM)	720.45	14.03	8.43	2.70	11.60	806.17	17.23	22.30	3.72	18.15
Rice Husk Dust (RHD)	521.62	13.02	13.00	1.60	10.36	644.26	16.48	19.30	2.20	13.12
N.P.K + PM`	781.04	16.21	17.33	1.97	19.44	811.56	17.84	34.00	3.03	22.52
N.P.K + RHD	503.63	11.36	19.00	1.13	15.86	616.17	16.38	21.30	3.17	17.19
PM+RHD	699.86	14.97	16.00	1.33	13.42	785.35	16.97	26.00	3.30	19.08
N.P.K + PM + RHD	643.05	15.86	15.00	1.17	12.19	770.44	16.32	17.70	2.07	14.04
$LSD_{(0.05)}$	0.0946	0.0418	7.64	Ns	9.21	0.1584	0.0368	12.93	ns	7.08

Table 5. Effect of integrated nutrient management on mineral content of sweet potato roots in 2019 and 2020 cropping seasons

Treatments	Phosphorus	Potassium	Calcium	Phosphorus	Potassium	Calcium
			(mg 100 g^{-1} sample)			
		2019			**2020**	
No manure	28.75	145.06	21.81	44.52	304.16	29.67
N:P:K	40.66	316.22	40.65	50.15	420.85	52.05
Poultry manure (PM)	38.33	304.27	43.81	55.05	411.52	54.85
Rice husk dust (RHD)	41.72	305.13	41.55	52.74	370.33	54.36
N:P:K + PM`	43.05	321.56	41.06	49.23	424.07	54.03
N:P:K + RHD	39.33	298.32	46.05	50.62	394.07	60.28
PM+RHD	42.57	275.15	44.28	57.62	430.65	57.92
N:P:K + PM + RHD	37.52	281.03	40.89	48.65	386.66	52.788
$LSD_{(0.05)}$	0.04	0.07	0.04	0.048	0.59	0.044

Table 6. Effect of integrated nutrient management on proximate composition of sweet potato roots in 2019 and 2020 cropping seasons

Treatments	Crude protein	Fat	Carbohydrate	Energy value	Crude protein	Fat	Carbohydrate	Energy value
	(%)			(kJ g^{-1})	(%)			(kJ g^{-1})
	2019				2020			
No manure	1.89	0.15	28.02	110.59	1.75	0.62	26.44	147.06
N.P.K	2.33	0.66	28.35	128.64	2.19	0.61	30.01	134.27
PoultryManure (PM)	2.07	0.67	28.83	129.55	2.16	0.57	29.44	131.64
Rice Husk Dust (RHD)	2.15	0.61	24.50	112.03	2.32	0.66	29.51	133.17
N.P.K + PM`	2.17	0.71	31.33	132.21	2.29	0.68	33.64	121.08
N.P.K + RHD	2.21	0.54	28.30	128.44	2.38	0.65	28.69	130.11
PM+RHD	1.95	0.61	29.52	126.25	2.54	0.74	27.49	122.90
N.P.K + PM + RHD	2.38	0.62	23.89	137.68	2.54	0.75	24..51	144.89
$LSD_{(0.05)}$	0.03	0.03	0.03	0.35	0.03	0.03	1.91	0.04

Table 7. Correlation coefficients between some growth, yield and nutrient attributes of sweetpotato (below diagonal) in 2019 and (above diagonal) 2020 cropping seasons

Year	Plant attributes	Fresh storage root yield (t ha^{-1})	Number of roots $plot^{-1}$	Above ground dry matter (g)	Crop growth rate (g m^{-2} day^{-1})	Crude protein (%)	Carbo-hydrate (%)	Starch (%)	Energyvalue (kJ g^{-1})	Phos-phorus (mg 100 g^{-1} sample)	Potas-sium (mg 100 g^{-1} sample)	Year
2019	Fresh root yield (t/ha)	**1.00**	1.00**	0.19	-0.12	0.38	-0.32	0.41	-0.19	-0.49	-0.37	2020
	Number of roots $plot^{-1}$	-0.17	**1.00**	0.19	-0.11	0.38	-0.32	0.41	-0.19	-0.49	-0.37	
	Shoot dry matter (g)	-0.26	0.18	**1.00**	0.15	0.72**	-0.55*	0.67**	-0.43	-0.36	-0.76**	
	Crop growth rate	0.26	0.22	0.97**	**1.00**	-0.02	-0.17	0.27	-0.33	-0.05	-0.05	
	Crude protein (%)	-0.42	0.37	0.19	0.09	**1.00**	-0.36**	0.61**	-0.28	-0.58*	-0.62*	
	Carbohydrate (%)	0.34	-0.20	-0.07	0.04	-0.71**	**1.00**	-0.79**	0.25	0.78**	0.76**	
	Starch (%)	0.18	0.15	0.12	0.16	0.22	-0.41	**1.00**	-0.70**	-.85**	-0.95**	
	Energy value(kJ g^{-1})	0.34	-0.16	-0.04	0.06	-0.66**	0.99**	-0.39	**1.00**	0.47	0.59*	
	Phosphorus	-0.16	0.51*	0.26	0.27	0.75**	-0.55*	0.62**	0.47	**1.00**	0.75**	
	Potassium	-0.09	0.42	0.24	.022	0.73**	-0.58*	0.63**	-0.52*	0.97**	**1.00**	

**$P \leq 0.01$, ns = not significant (2-tailed).

CONCLUSION

Integrated nutrient management (INM) of organic and inorganic fertilizers could be beneficial by increasing growth and storage root yield of sweet potato in the humid tropics. The results from the study highlighted that combined application of N:P:K + poultry manure to sweet potato is adjoined to be a viable strategy aimed at improving both storage root yield and root quality of the test crop.

DECLARATION AND CONFLICTS OF INTERESTS:

Wehereby declare that we are the authors of the submitted manuscript and that the manuscript is our original work which has not been published in any other journal and has not been submitted anywhere for publication and there are no conflicts of interests. You are very free to edit the manuscript to suit the requirements of your reputable Journal.

REFERENCES

Balemi, T. (2012). Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato inEthiopia. Journal of Soil Science and Plant Nutrition, 12(2), 253-261.

Bhagsari, A.S., Ashley, D.A. (1990). Relationship of photosynthesis and harvest index of sweet potato yield. J. Hort. Sci., 111, 288-293.

Bremner, J.M.(1996). Nitrogen-Total. In: Methods of Soil Analysis, Chemical Methods, Ed3, 5. Soil SciencSociety of American and American Society of Agronomy, Madison,Wisconsin, pp, 1035-1122

Bouyoucos, G.J.(1962). Hydrometer method improved for making particle size analyses of soils. Agron. J., 54, 464-465.

Chang, S.K.C.(2003). Protein Analysis. In: Food Analysis. (Ed.) Nielsen, S.S. Kluwer Academic Publishers, NewYork.

Dapaah, H.K., S.A. Ennin, O. Safo-Kantanka, V.M. Anchiinan, M.M. Buri, A.A. Danjyi, and Otoo, J.A (2004).TIP, MOFA, Kumasi, Ghana. P, 17.

Degras, L. (2003). Sweet potato. The tropical agriculturalist. Macmillan Publisher, Kuala Lumpur, Malaysia.

Donado-Pestana, C.M., J.M. Salgado, A. R. de Oliveira, P.R. dos Santos, and Jablonski, A. (2012). Stability of carotenoids, total phenolics and in vitro antioxidant capacity in the thermal processing of orange-fleshed sweet potato (*Ipomoea batatas* Lam.) Cultivars grown in Brazil. Plant Food Hum. Nutr., 67, 262–270.

FAO (Food and Agriculture Organization). (2016). Food and Agriculture Organization Statistical Database for Agriculture, Rome. http://faostat.fao.org, 102 p.

Egbe, O.M., S.O. Afuape, and Idoko, J.A. (2012). Performance of improved sweet potato (*Ipomoea batatas* L.) varieties in Makurdi, Southern Guinea Savanna of Nigeria. Am. J. Exp. Agric. 2(4):573-86.

Esan, V.I., O.O. Omilani. and Okedigbo, I. (2021). Effects of organic and inorganic fertilizers on sweetpatato production in Iwo, Nigeria. African Journal of plant Science, 15(5), 131-137. DOI:10.5897/AJPS2021.2130.

Igbokwe, P.E., L.C. Huam, F.O. Chukwuma and Huam, J. (2005). Sweet potato yield and quality as influenced by cropping systems. Journal of Vegetable Science, 11, 35-46.

Islam, S.N.,T. Nusrat, P. Begum, and Ahsan, M. (2016). Carotenoids and β-carotene in orange fleshed sweet potato: A possible solution to vitamin A deficiency. Food Chem., 199, 628–631.Jackson,

Magagula Nein, O.E.M., R.L. Rhykerd, andWhykerd, C.L. (2010). Effects of chicken manure on soil properties under sweet potato (*Ipomea Batatas* (L.) Lam) culture in Swaziland. American Eurasian Journal of Agronomy, 3(2), 36-43.

Mbah, C.N. and Onweremadu, E.U.(2009). Effect of organic and mineral fertilizer inputs on soil and maize grain yield in an acid ultisol in Abakaliki, southeastern Nigeria.American-Eurasian J. Agron., 2(1), 7–12.

Mbah, E. U. and Eke-Okoro, O. (2015). Relationship between some growth parameters, dry matter content and yield of some sweet potato genotypes grown under rainfed weathered ultisols in the humid tropics.

Journal of Agronomy, 14(3), 121-129.McLean, E.O. (1982). Soil pH and lime requirement. In: Page, A.L., R.H. Miller, andD.R. Keeney (eds.), Methods of soil M.L.(1973_. Soil Chemical alysis. Prentic Hall of India, PV M. Lvt. Ltd., New elhi, pp, 498.

James, C.S.(1995). Analytical Chemistry of Foods. 1st Edn., Chapman and Hall, New York. 178 pages.

Kathabwalika, D.M.,E.H.C. Chilembwe, V.M. Mwale, D. Kambewa, and Njoloma, J.P.(2013). Plant growth and yield stability of orange fleshed sweet potato (Ipomoea batatas) genotypes in three agro-ecological zones of Malawi. Int. Res. J. Agric. Sci. Soil Sci., 3(11), 383-392

Kookana, R.S., A.K. Sarmah, K.E. Van Zwieten, and Singh, B.(2011).Biochar Application to soil Agronomic and Environmental Benefits and unintended consequences. Advances in Agronomy, 112, 103 – 143. doiiorg.1016/Ba78-0-il-J-385538-I:00003-l

Kubota, F., R. Kenof, M.Yatomi, and Agata, M.(1992). Scoring methods of stomatal aperture of sweet potato (*Ipomoea batatas* Lam.) leaf. Japan J. Crop Sci., 61, 686-688.

Low, J., R. Kapinga, D. Cole, C.Loechl, J. Lynam, and Andrade, M, (2009). Challenge theme paper 3: Nutritional impact with orange-fleshed sweetpotato (OFSP). Unleashing the potential of sweetpotato in Sub-Saharan Africa (pp, 73–105). CIP

Lu, S.G., F.F. Sun, and Zong, Y.T. (2014). Effects of Rice husk Biochar and coal Fly ash on some physical properties of Expausive Clayey Soil (Versitol) cantenu, 114, 37 – 44. http://doi.org/10.1016/j.catena.2013.10.014

analysis, 2nd edition, Part 2. American Society of Agronomy, Madison, WI, USA, pp, 199-224.

Moorthy, S.N. (1991). Extraction of starches from tuber crops using ammonia. Chemistry, Carbohydrate Polymers, 16, 391-398.

Mukhtar, A.A., B. Tanimu, U.L. Arunah, andBabaji, B.A. (2010). Evaluation of the agronomic characters of sweet potato varieties grown at varying levels of organic and inorganic fertilizer. **World J. Agric. Sci.,**6(4), 370-373.

Mwanga, R.O.M., B. Odongo, C. Ocittip'Obwoya, R.W. Gibson, N.E.J.M. Smit, and Carey, E.E. (2001). Release of five sweet potato cultivars in Uganda. HortScience, 36(2), 385-386.

Nedunchezhiyan,M.,Srinivasulu, R.D. (2004). Growth, yield and soil productivity as influenced by integratednutrient management in rainfed sweet potato. Journal of Root Crops, 30(1), 41-45.

Nelson, S.W., and Sommers, L.E. (1982). Total carbon, organic carbon and organic matter. In: In: Page, A.L., R.H. Miller, D.R. Keeny, (eds) methods of soil analysis part 2. American Society of Agronomy, Madsison, 539-579.

NEST (Nigeria Environmental Study Action /Team).(1991). Nigeria's Threatened Environment: A National Profile. Nigeria: NEST.

Nunes, J.C., J.A. Da Silva, M.B.G. Neto, and Bezerra, J.C. (2020). Effect of combined organic and inorganic fertilizer application on soil attributes, yield and quality of sweetpotato (*Ipomoea batatas* L.). Journal of Agricultural Studies, 8(4), 252. DOI:10.5296/jas.v814.17217.

Nwaigwe, G.O., G.E.Nwofia,I.I.M. Nwankwo, and Afuape, S.O. (2017). Effect of orgnic and inorganic fertilizers on sweetpatoto genotypes for yield stability. Nigerian Agricultural Journal, 48(2), 158-164.

Obi, I.U. (2002). Statistical methods of detecting differences between treatment means methodology issues in laboratory and field experiments. AP Express Publishing Company, Ltd., Nsukka, Nigeria.

Onunka, N.A., L.I. Chukwu, E.O. Mbanasor, and Ebeniro, C.N. (2012). Effect of organic and inorganic manures and time of application on soil properties and yield of sweet potato in a tropical ultisol. J. Agric. Soc. Res.,12(1), 182-193.

Onwuka, G.I. (2005) Food analysis and instrumentation. Theory and Practice. Naphatali prints, A Division of G. H. support Nigeria limited Surulere Lagos, Nigeria. pp, 119 – 121.

Patricia, I., and Bansal, S. K. (1999). Potassium and Integrated nutrient management in potato. International Potash Institute Seminar, 6-11 December 1999, New Delhi, India.

Radford, D.J. (1967). Growth analysis formulae their use and abuse. Crop Sci., 7, 171-175.

Snedecor, G.W. and Cochran, W.G. (1980). Statistical methods, 7th ed. Iowa State University Press, Ame.

Souza, R.S., andChaves, L.H.G.(2016). Doses de fósforo e potássio no desenvolvimento da cultura de Crambeabyssinica. Revista Verde de Agroecologia e DesenvolvimentoSustentável, 11(2), 71-75.

Sui, Y., J. Goo, C. Liu, W. Zhang, Y. Lan, S. Li, and Tang, L. (2016). Interactive effect of straw-derived biocher and N fertilization on soil storage and rice productivity in rice paddies of Northeast China. Science o the total Environment, 544, 203-210

Szarvas, A., M.S. Hódi, and Monostori, T.(2019). The effect of plant density on the yield of sweet potato. Acta AgrariaDebreceniensis, 74, 173-177.

Varela, M.O., E.B. Rivera, W.J. Huang, C. Clien, and Wang, Y.M. (2013). Agronomic properties and characterization of Rice husk and wood biochars and their effects on the growth of water Spinach in a field test. Journal of soil science and plant Nutrition. 13, 251-266

Walkley, A. and Black, A.I. (1934). In: Examination of the Degtagareff. Methods of determining soil organic

matter and a proposed modification of the chronic acid titration method. Soil Sci., 37, 29-38

Watson, D.J. (1952). The physiological basis of variation in yield, pp. 101-145. In: Norman, A.G. (ed.). Advances in Agronomy 4, Academic Press, New York.