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Effects of NPK fertilizer on growth and yield of Nigerian turmeric (*curcuma longa* linn.) germplasm in coastal rainforest ecology of Nigeria

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ABSTRACT

The study investigated the responses of 10 Turmeric Nigerian Curcuma Longa (NCL) Germplasm, to NPK nutrient rates and its effect on some soil properties. The experiment laid out, was a 3 x 10 factorial in RCBD, to evaluate the growth and yield performance on coastal rainforest soil in Nigeria. The following data were collected: soil physico-chemical properties, tiller count, leaf area (cm^2), plant height (cm), plant biomass (mtons ha^{-1}), economic yield (mtons ha^{-1}) and harvest index. Also, linear correlation matrix and traits variability of the accessions were characterized. Data were subjected to ANOVA, as outlined for factorial in RCBD. Treatment means were separated using Fisher's least significant differences ($p < 0.05$). The soil is acidic (3.60 - 5.20), low total Nitrogen (1.10 - 1.12 g kg^{-1}) and exchangeable bases with Potassium (0.02 – 0.15 cmol kg^{-1} soil). Nutrient rates at 150 kg N, 50 g P_2O_5, and 50 kg K_2O (500 kg ha^{-1}NPK), significantly ($p<0.01$) improved tiller count $clump^{-1}$ (4.85), leaf area (187.70 cm^2) and plant height (54.97 cm), better than the control 2.65, 156.60 cm^2 and 45.93 cm, but similar with the nutrient rate of 200 kg N, 100 kg P_2O_5, and 100 kg K_2O (1000 kg ha^{-1}), which recorded 4.19, 183.20 cm^2 and 54.54 cm, respectively. The correlative coefficient values to each trait, was positively significant ($p < 0.01$). Hence, tiller number $clump^{-1}$, broader leaf area and plant height are complementary and serve as good growth indices for yield determination. The Economic yield differed significantly ($p < 0.05$) with nutrient rate at 150 kg N, 50 kg P_2O_5, and 50 kg K_2O, with accessions NCL 37 - 70.85 mtons ha^{-1} and NCL 39 - 45.90 mtons ha^{-1}, better than the control (36.31 and 34.38 mtons ha^{-1}), but similar with nutrient rate at 200 kg N, 100 kg P_2O_5, and 100 kg K_2O of NPK 1000 kg ha^{-1}, which gave 80.36 and 58.10 mtons ha^{-1}. Threfore, Nutrient rate of NPK 20:10:10 at 500 kg ha^{-1}, was cost effective. Turmeric accessions NCL 37 and 39 that were characterized are selected for farmers in the ecological zone.

1.0 Introduction

Turmeric, *Curcuma longa* Linnaeus (1753), is an underground rhizomatous herbaceous perennial monocot plant of about 1 m tall, from the ginger family Zingiberaceae (Ravindran *et al.,* 2007). India is the centre of domestication, but widely cultivated in the tropical region. Turmeric rhizome is divided into mother rhizome of bulb, and its lateral auxiliary branches known as finger (daughter rhizomes). These are separated into primary rhizome (pear shaped / bulb turmeric), secondary rhizome (cylindrically shaped), tertiary rhizome, quaternary rhizome etc. and noodles which are root out-growth.

Turmeric is known differently, by the Meo, Ukele and Efik tribes of Cross River call it *Onjonigiho*, *Legokejong* and *Adang Uneng* (Olojede *et al*., 2003). It is known as *Utu Isong* in Ibibio, *Jita* in Nupe, *Mosoro* and *Gangamo*, *Haldi* in India, *Jiang Huang* in China (Khanna, 1999), and *Turmerica* in French speaking country. The rhizomes are boiled for 30-45 minutes, dried and ground into a deep-orange yellow powder used in ceremonial purposes, myths and for alternative medicine. The powder as curry spice impart colour and enhances the flavour of vegetable, meat dishes and give boiled white rice a golden aromatic colour (FAO, 2004). It is also used for dyeing fabric and research purposes as an Indicator - litmus paper.

The active ingredients of Turmeric plant are mixture of 3 curcuminoids, Turmeric oil, Turmeric oleoresins from leaves and flowers (monoterpenes) and from roots and rhizomes (sesquiterpenes). Curcumin is linked to the anti-inflammatory, antifungal, antibacterial, antioxidant, anticancer, antiviral properties of Turmeric. Nitrogen (N) as one of the three major nutrients is involved in chlorophyll formation and it influences stomata conductance and photosynthetic efficiency. Potassium (K) plays catalytic roles in the plant, and inadequate supply of K manifests itself as chlorotic lesions and drying of leaf tips, yellowing of older leaves first, poor growth which results to poor yield and low resistance to coldness and drought (Oya, 1972). Adequate supply of K promotes N uptake efficiency of plants, due to its stimulant effect on plant growth. Sufficient K nutrition enhances yields development and disease resistance of root and tuber crops (Janson, 1978). While, excessive doses of K play inhibitory action on the absorption of other plants nutrients.

The demand for turmeric in the world is exacerbating without a proportional increase in production. This is due to increase awareness of its utilization by the food and pharmaceutical industries (Adeniji, 2004), this necessitate Turmeric cultivation. Africa continent has favourable agro-climatic conditions that can enhance turmeric productivity. However, the research on turmeric production and quality in Nigeria is still at its infancy with no recommended variety to farmers. Farmers in sub-Saharan Africa can only manage to produce on the field an average yield of 5.8 tonnes hectare^{-1}. Studies revealed a higher yield of 23 tonnes hectare^{-1} in 2007 (Olojede *et al., 2007*), while in India fresh yield of 30 tonnes hectare^{-1} were obtained from mother rhizome (Satish *et al.,* 1997).

The short fall in yield can be attributed to diseases and insect pests' attack in farmers' fields (Amtmann *et al.*, 2008), depletion of soil fertility and soil degradation arising from land use intensification, wide spread removal of crop residues as animal feed and fuel (Oikeh *et al.,*2003). Couple with blanket application of scarce fertilizer at sub-optimal level without soil tests due to limited financial resources, lack of technical know-how, have led to low productivity (Petel and Chudawat, 1998). There is dearth of information on the agronomic practice for Turmeric production in Nigeria. The objective of the study is to evaluate the yield potentials and performance of 10 Turmeric accessions to NPK fertilizer rates on beach coastal soil.

2.0. Materials and Methods

2.1. Field study

The Experiment was conducted in the year 2018, at the project farm of Cross River Basin Development Authority (CRBDA) in Abak, Akwa Ibom State. This is located in the Humid (rainforest ecology), at latitude 05^0 98^1N and longitude 07^0 47^1E, at elevation 61 m above mean sea level (msl). The coordinates and the altitude were obtained using Garmin Etrax 2000 - global positioning system (GPS) meter.

2.2. Experimental design

The experiment was a 3 x 10 factorial in a Randomized Complete Block Design (RCBD), with two treatments (NPK Fertilizer and 10 Turmeric Accessions), replicated three times.

2.3. Treatment factors

Factor A: The treatments comprises of 3 Fertilizer rates of NPK 20:10:10. These are - 0 kg ha^{-1} NPK (Control), 500 kg ha^{-1} NPK 20:10:10, contain nutrient rates of 150 kg N, 50 kg P_2O_5, and 50 kg K_2O, and 1000 kg ha^{-1} supplied 200 kg N, 100 kg P_2O_5, and 100 kg K_2O. The Nutrient rates were applied in two splits (1 and 2 months after planting) at the rate of 20.83 g plant^{-1} for 500 kg ha^{-1} and 41.44 g plant^{-1} for 1000 kg ha^{-1}.

Factor B: The treatments comprise of 10 Turmeric accessions, replicated 3 times. The 3 Fertilizer rates x 10 Accessions gave 30 treatments combination

2.4. Land Area

Spacing: 0.30 m x 0.20 m within plots, which gave a population of 166,666.67 plants ha^{-1}. Each plot contains 10 plants and samples was taken from three middle plants. The block interval was 1 m apart. The Land used was 750 m^2.

2.5. Determination of Nutrient rates

The nutrient rates were determined, using the Plant / Land Area Ratio cultivated. Thus, as 500 kg NPK 20:10:10 was applied hectare^{-1}, what quantity needed per 750 m^2 Area of Land.

Nutrient rates for the Experimental fields:

$$500kg \rightarrow 10{,}000m^2$$

$$Xkg \quad \rightarrow \; 750m^2$$

$$Cross \quad multiply$$

$$\frac{500 \times 750}{10{,}000} = \frac{375{,}000}{10{,}000}$$

$$= 37.50kg\ NPK / 750m^2$$

$$= \frac{37.50}{1800} = 0.02083kg = 20.83g\ NPK\ plant^{-1}$$

For 1000 kg NPK nutrient rate applied, it gave:

37.50 kg x 2 = 75 kg NPK 750 m^{-2}; and 20.83 g x 2 = 41.66 g NPK plant $^{-1}$.

Note: To get the actual nutrient rate per stand, divide the measured quantity by the plant population of the land area. Also, the NPK nutrient application rate of 150 kg N, 50 kg P_2O_5 and 50 kg K_2O from NPK 20:10:10 + Urea, was achieved by calculating first the quantity of P and K applied.

Formula:

$$quantity\,required \quad (Q) = \frac{R - rate}{C - fertilizer\ grade} \times \frac{100}{1}$$

$$Q = \frac{60}{10} \times \frac{100}{1} = 600kg$$

Since 60 kg P_2O_5 ha^{-1} is contain in 600 kg ha^{-1}, and 500 kg ha^{-1} was administered.

Therefore,

$$60\,kg \rightarrow 600\ kg/ha$$

$$Xkg \rightarrow 500\ kg/ha$$

Cross multiply

$$\frac{60 \times 500}{600} = \frac{30{,}000}{600}$$

$$= 50\,kg\ P_2O_5\ and\ 50\ kg\ K_2O$$

The amount of N in 500 kg nutrient rate of NPK 20:10:10 is:

R = (Q x C) / 100

$$\frac{500 \times 20}{100} = \frac{10{,}000}{100}$$

$$= 100\,kg\ N/ha$$

Therefore, the balance of 50 kg N ha^{-1} came from Urea fertilizer.

$$46\,kg\ N \equiv 100\ kg\ Urea$$

$$50\,kg\ N = \frac{50}{46} \times \frac{100}{1} = 108.70\ kg\ Urea\ ha^{-1} \approx 2.17\,bags$$

To get per 750 m^2 land area

$$108.70 \rightarrow 10{,}000\,m^2$$

$$X \rightarrow 750\,m^2$$

$$\frac{108.70 \times 750}{10{,}000} = \frac{81{,}525}{10{,}000} = 8.15\ kg\ Urea/750\ m^2$$

$$\therefore \frac{8.15}{1800} = 0.00453\,kg = 4.53\,g\ Urea\ \ plant^{-1}$$

2.6. Land preparation

The land was ploughed, harrowed and raised beds made, before Turmeric propagules was established.

The NPK 20:10:10 Fertilizer + Urea were applied in 2 split doses, at 30 and 60 days after planting (DAP). Banding application method was used.

Hand weeding was done twice manually with hoe.

Harvesting: The rhizome was harvested at 9 months after planting (MAP), using hoe. Yield was measured in rhizome $clump^{-1}$, $plot^{-1}$ and extrapolated to metric tonnes $hectare^{-1}$.

2.7. Data collection - Soil sampling and Analysis

Soil composite samples were taken at random from a soil depth of 0 - 15 cm using a tubular auger. This was done before planting and at harvest $treatment^{-1}$ $block^{-1}$.

Physical properties

Particle size distribution: Soil samples was air-dried and sieved through a 2 mm mesh. A hydrometer method by Bouyocous (1951) was used to analyze the fine sand, coarse sand, silt and clay fractions. The soil textural triangle was used to classify the textural class. Bulk density: The weight of oven - dried soil at 105^{o}c was divided by its volume, as described by Grossman and Reinch (2002). Hydraulic conductivity: This was determined with the constant head permeameter method, as described by Klute (1986).

Chemical properties

Soil pH: 10 g of soil was weighed into a conical flask and 25 ml of distilled water and, or acid was added and stirred gently for 30 mins. The pH values were read by glass electrometric meter – PHS25 Hanna instrument, at a Soil: Water ratio of 1:2.5; and or Soil: Potassium Chloride ratio of 1: 2.5 as described by Udo et al. (2009). Available phosphorus: This was determined with Bray P-1 Extraction Method of Bray and Kurtz (1945). Phosphorus concentration in the extract was measured by the blue colour method as described by Murphy and Riley (1962). Organic carbon: This was determined by Walkley and Black (1934), Wet Digestion Method. Total nitrogen: The Macro-Kjeldhal Digestion Distillation Method (Bremner, 1965) was used to determine total Nitrogen concentrations. Exchangeable bases: Magnesium (Mg), Calcium (Ca), Sodium (Na) and Potassium (K) were extracted with neutral ammonium acetate (NH_4Ac) at pH 7. K^+ and Na^+ contents were read with the aid of Flame Photometer, while Ca^{2+} and Mg^{2+} were determined by EDTA complexiometric titration method (Jackson, 1965). Exchangeable acidity: was extracted using 1molar KCl solution. Total acidity from the exchangeable hydrogen was determined by titration, as outlined in IITA manual No.1 (1979). Effective cation exchange capacity (ECEC): This was determined by summation method i.e. addition of Total exchangeable bases and exchangeable acidity (Soil Survey Staff, 2010).

Base saturation: This was determined by calculation, using the formula: -

% BS = (TEB / ECEC) x 100

2.8. Agronomic characters

1. Percent sprouting count $replication^{-1}$ was taken as

$$\frac{Number\ of\ sprouted\ shoots\ per\ plot\ per\ bag}{Total\ number\ of\ setts\ planted\ per\ plot\ per\ bag} \times \frac{100}{1}$$

2. Establishment count $plot^{-1}$ $replication^{-1}$ was taken days after planting (DAP).
3. Coefficient velocity of emergence (CVE) at 50% and 100% were calculated using Kotowski (1978) formular.

$$CVE = \frac{1}{N_1T_1 + N_2T_2 + \ldots\ldots N_XT_X} \times \frac{100}{1}$$

4. Number of tiller $clump^{-1}$, taken 5 months after planting (MAP).
5. Plant height (cm) was measured 5 months after planting (MAP). This was done from four randomly tagged plants from the net plot (two middle rows).
6. Leaf area (cm^2) and leaf area index (LAI):
The leaf area was determined in situ without destroying the canopy using the regression equation Y = 2.46 + 0.640 (X) where Y = leaf area and X = product of leaf length and width (L x W). The leaf area estimation method of (Reddy *et al.,* 1989) was adopted.
7. Plant biomass (g) $clump^{-1}$ and kg ha^{-1}.
8. Rhizome yield (g) $clump^{-1}$ and kg ha^{-1}.
9. Harvest index (HI) is the ratio of fresh rhizome yield over biomass yield (whole plant weight) no unit.

2.9. Statistical analysis

Analysis of variance (ANOVA), is done to identify differences between means, according to the procedure outlined for RCBD, where significance was confirmed at $p < 0.05$. Treatment means were compared using Duncan Multiple Range Test (DMRT) and Fisher's Least Significant Difference (LSD) test, and significance was accepted at 5% and 1% levels of probabilities as outlined (Genstat, 2005, Obi, 2002 and SAS, 2013).

3.0. Results and Discussion

3.1. Results

3.1.1. Soil physico - chemical properties of the experimental fields

The physical characteristics of the analyzed soils in Table 1 before planting indicates that the textural class of the chosen sites is sandy. Sand fraction ranged from 24 - 64%, while Clay particle size distribution of 7% in 2017 and 9% in 2018, did not differ before planting and at harvest to different rates of NPK fertilizer applied respectively. The mean bulk density value was 1.67 g cm-3 before planting, and 1.46 g cm-3 mean values at harvest. This compaction effects contributed to the high hydraulic conductivity (cm hr-1) at the experimental sites.

The chemical properties reveals that the pH in water (1:2.5) and Potassium Chloride (KCl) (1:2.5) are both acidic in nature (3.60 - 5.20). The organic matter and organic carbon (g Kg-1) content of the soil increased marginally from 29.30 g kg-1 (500 kg NPK ha-1) to 30.10 g kg-1 (1000 kg NPK ha-1) in 2012. The total nitrogen content was relatively low (1.12 g kg-1) at planting and decline at harvest (1.10 g kg-1) in 2012 at the control plots (0 kg NPK ha-1). Conversely a decline was recorded in total nitrogen content as the fertilizer rates increase from 500 - 1000 kg NPK ha-1. This was due to leaching, heavy rainfall, adequate macro and micro spore spaces (%) at the experimental sites.

Exchangeable bases in cmol kg-1 soil: The mean value of potassium (0.09 – 0.15 cmol kg-1) across the treatments were below the critical levels of 0.18 – 0.20 cmol kg-1

Table 1: Soil physico - chemical properties of the experimental fields

Soil properties / Time / Year	Location (Abak) 2018			
	At planting (Kg NPK ha^{-1})	At harvest (Kg NPK ha^{-1})		
	0	0	500	1000
Physical properties				
Particle size distribution (%)				
Clay	5	9	9	9
Silt	5	3	3	3
Fine sand	25	24	31	29
Coarse sand	61	64	57	59
Textural class	Sand	Sand	Sand	Sand
Field capacity 60cm tension (%)	20.29	25.63	.	.
Field saturation point (%)	.	39.79	.	.
Bulk density (g / cm^3)	1.67	1.45	.	.
Moisture content (%)	2.30	28.62	27.84	25.73
Micro spore space (%)	.	25.52	.	.
Macro spore space (%)	.	19.76	.	.
Total porosity (%)	36.98	45.28	.	.
Hydraulic conductivity (cm / hr)	75.76	64.39	.	.
Chemical properties				
pH value in water 1: 2.5	4.30	4.90	4.70	4.80
pH value in KCl 1: 2.5	3.60	3.80	3.60	3.80
Organic carbon (g kg^{-1})	12.50	9.00	9.00	7.90
Organic matter (g g^{-1})	21.50	15.50	15.50	13.60
Total nitrogen (g kg^{-1})	1.12	0.84	0.84	0.70
Available phosphorus (mg kg^{-1})	40.10	77.41	65.29	76.48
Base saturation (%)	31.30	81.96	62.00	60.48
C .E .C in Cmol kg^{-}	10.80	5.60	10.00	8.40
Exchangeable bases in cmol kg^{-1} soil				
$Sodium^{+}$	0.04	0.06	0.11	0.13
$Potassium^{+}$	0.14	0.13	0.09	0.15
$Calcium^{2+}$	1.80	2.80	2.80	3.60
$Magnesium^{2+}$	1.40	1.60	3.20	1.20
Exchangeable acidity in cmol kg^{-1} soil				
$Aluminium^{3+}$	0.80	0.00	0.00	0.00
$Hydrogen^{+}$	0.80	3.60	4.40	3.60

3.1.2. The effects of Nutrients rates and Accessions on seedling emergence, growth and rhizome yield traits of Turmeric at Abak in 2018 cropping season

There were significant differences ($p < 0.01$) with the application rate of 500 kg NPK ha^{-1} which recorded higher tiller number $clump^{-1}$ (4.85) and plant height (54.97 cm), but statistically similar when 1000 kg NPK ha^{-1} was applied, than the control treatment (Table 2).

Conversely, the yield traits performed best with increased NPK fertilizer rates to 1000 kg NPK ha^{-1}, for plant biomass (32.03 mtons ha^{-1}), economic yield (24.36 mtons ha^{-1}), and harvest index ratio (0.78%). The control plots had the lowest mean yield weight of 13.92 mtons ha^{-1}.

The NPK nutrient application rate of 1000 kg ha^{-1}, recorded the highest mean yield weight of 24.36 mtons ha^{-1}, which is statistically similar to 500 kg NPK ha^{-1} (21.25 mtons ha^{-1}) when compared.

The economic yield differed significantly ($p < 0.01$), with the highest mean yield of 24.32 mtons ha^{-1} at 1000 kg NPK ha^{-1}. This is similar statistically with the mean yield of 20.09 mtons ha^{-1} at 500 kg NPK ha^{-1}. The control had the lowest mean yield of 13.40 mtons ha^{-1}.

3.1.3. Effects of Accessions on seedling emergence, growth and rhizome yield traits of 10 Turmeric accessions at Abak

For accessional differences, accession NCL 37 recorded the highest rhizome yield across fertilizer treatments, followed by NCL 39. Accession NCL 37 had the highest rhizome yield weight of 80.38 mtons ha^{-1} at 1000 kg NPK ha^{-1}, which is similar statistically to 70.85 mtons ha^{-1}, at 500 kg NPK ha^{-1}. The control recorded the lowest yield of 36.31 mtons ha^{-1} $fertilizer^{-1}$ treatment when compared, respectively. The ANOVA result in Table 3, shows that days to 100% sprouting, differed significantly ($p < 0.01$) among the accessions.

Table 2: Effects of NPK 20:10:10 nutrient rates on growth and rhizome yield traits

NPK rates kg Hec^{-1}	Tiller count $clump^{-1}$	Leaf area (cm^2)	Plant height (cm)	Plant biomass $Plant^{-1}$ (g)	Plant biomass Hec^{-1} (tons)	Economic yield $Plant^{-1}$ (g)	Economic yield Hec^{-1} (tons)	HI
0kg	2.65	156.6	45.93	116.7	19.44	83.50	13.92	0.67
150kgN, 50kgP_2O_5 and 50kgK_2O	4.85	187.7	54.97	166.4	27.73	127.5	21.25	0.75
200kgN,100kgP_2O_5 and 100kgK_2O	4.19	183.2	54.54	192.2	32.03	146.2	24.36	0.78
Mean	3.90	175.8	51.81	158.4	26.40	119.1	19.84	0.73
F-LSD	***	ns	**	***	***	***	***	***
(p<0.05)	0.7117		7.257	0.049	8.163	0.038	6.242	0.06

Accession NCL 37 had the shortest (51) days, while accessions NCL 60 and NCL 52, sprouted late (76 and 77).

Emergence interval in days (50%) differed significantly at 5% level of probability. Accessions NCL 29, NCL 30 and NCL 45, recorded the shortest sprouting day's interval, which ranged from 7 - 8, while accessions NCL 37, NCL 34 and IBF 222 had the longest sprouting days' interval (16 - 18).

Coefficient velocity of emergence 100%, differed significantly at 1% level of probability. Accession NCL 37 recorded the fastest velocity rate (0.24%), while accessions NCL 52 and NCL 38 had the slowest rate (0.15%).

Leaf area (cm^2), differed significantly ($p < 0.01$) among the accessions. Accessions NCL 37 and NCL 39 recorded the highest leaf area (260.70 cm^2 and 542.60 cm^2), while accessions NCL 34 and NCL 60 had the smallest leaf area (98.50 cm^2 and 99.7 cm^2).

Plant height, differed significantly ($p < 0.01$) among the accessions. Accession NCL 37 recorded the tallest (98.40 cm) height, while accession NCL 60 had the least (39.90 cm).

Plant biomass (g) $plant^{-1}$, had a highly significant difference ($p < 0.01$) among the accessions. Accessions NCL 37 and NCL 39 recorded the heaviest biomass of 390.30 g and 465.50 g, while accession NCL 34 had the least (56.9 g).

Plant biomass, differed significantly ($p < 0.01$), with accessions NCL 37 and NCL 39 recording heavier biomass of 65.06 mtons and 77.58 mtons ha^{-1}, while accession NCL 34 had the least biomass weight (9.48 mtons ha^{-1}).

Economic yield (g) $plant^{-1}$, differed significantly ($p < 0.01$) among the accessions. Accessions NCL 37 and NCL 39 recorded the heaviest yield of 282.00 g and 385.50 g, while accessions NCL 34 and IBF 222 had the lowest yield of 44.80 g and 47.60 g.

Yield tonnes $hectare^{-1}$, differed significantly ($p < 0.01$) among the accessions. Accessions NCL 37 and NCL 39 recorded the heaviest yield of 64.25 and 47.00 mtons hec^{-1}, while accessions NCL 34, NCL 38, NCL 29 and IBF 222, which ranged from 7.47 mtons - 9.75 mtons hec^{-1}, had the lowest yields, respectively.

3.1.4. Fertilizer x Accessions interaction effects on seedling emergence, growth and rhizome yield traits of 10 Turmeric accessions at Abak

The data in Table 4 shows significant ($p < 0.05$) interaction effects among the treatments combination (Fertilizer x Accession) in three out of nineteen characters evaluated.

The emergence interval in days between 1-50% sprouting, recorded the shortest mean interval of 11 days, at the control plots over the fertilizer treated plots. Accession NCL 29 recorded the shortest and fastest interval of 3 days at 500 kg NPK ha^{-1}. Accessions NCL 29, 45 and IBF 222, recorded the shortest and fastest interval of 3, 4 and 5 days, when NPK 20:10:10 of 500kg, 1000kg and 0 kg treatments were administered. Linear correlation matrix on some traits of 10 Turmeric accessions at Abak

The correlative coefficient responses for seedling emergence, growth and yield attributes of 10 Turmeric accessions, with 3 fertilizer rates of NPK 20:10:10 is shown in Table 5.

Table 3: Effects of Accessions on seedling emergence, growth and rhizome yield traits of 10 Turmeric accessions at Abak

Accession	Days to 100% sprouting	Emergence interval btw 1-50% sprouting	Coefficient velocity of emergence 100%	Tiller count clump^{-1}	Plant height (cm)	Plant biomass		Economic yield	
						Plant^{-1}(g)	Hec^{-1} (tons)	Plant^{-1}(g)	Hec^{-1}(tons)
NCL29	72.81	6.78	0.16	4.96	123.6	40.48	78.50	58.50	9.75
NCL30	68.26	7.06	0.18	4.77	111.8	42.60	81.50	60.50	10.08
NCL34	72.23	15.78	0.17	4.00	99.70	40.67	56.90	44.80	7.47
NCL37	51.41	18.34	0.24	3.44	542.6	98.40	465.5	385.5	64.25
NCL38	75.47	11.22	0.15	3.57	125.1	52.17	78.20	56.60	9.44
NCL39	64.14	12.82	0.19	3.20	260.7	66.40	390.3	282.0	47.00
NCL45	64.18	8.12	0.18	3.95	131.6	45.80	121.8	83.80	13.97
NCL52	76.24	12.77	0.15	3.90	115.4	43.82	95.00	68.80	11.47
NCL60	76.64	10.31	0.16	3.85	98.5	39.90	89.00	62.50	10.41
IBF222	70.53	16.06	0.17	4.63	111.0	41.58	82.50	47.60	7.94
Mean	69.19	11.93	0.18	4.03	172.0	51.18	153.9	115.1	19.18
F-LSD	***	**	***	Ns	***	***	***	***	***
(p<0.05)	5.578	6.595	0.0149		86.97	14.13	0.087	0.067	11.10

Table 4: Fertilizer x Accessions interaction effects on seedling emergence, growth and rhizome yield traits of 10 Turmeric accessions at Abak

NPK Kg Hec^{-1}	29	30	34	37	38	39	45	52	60	222	Mean	F-LSD (p<0.05)	C.V%
Emergence interval in days between 1-50% sprouting													
0	7.60	5.60	21.27	22.27	5.60	16.27	6.55	6.60	11.05	4.55	10.74		
500	2.60	9.60	15.27	19.03	11.34	9.27	13.34	14.93	11.27	9.34	11.60		
1000	10.27	5.93	10.60	12.60	16.93	12.93	4.34	16.93	8.55	34.98	13.41 (11.92)	11.42**	59.46
Tiller count clump^{-1}													
0	4.37	3.04	2.17	1.97	3.03	2.53	2.53	2.23	2.53	2.33	2.65		
500	5.74	5.70	5.11	4.17	3.51	3.42	4.77	5.84	5.91	4.51	4.87		
1000	4.64	5.11	4.31	3.84	4.04	3.49	4.37	3.31	2.87	6.49	4.25 (3.92)	Ns	32.91
Leaf area (cm^2)													
0	111.0	85.40	64.00	511.70	121.0	182.60	141.2	126.1	79.80	108.8	153.10		
500	152.2	127.4	114.60	522.30	99.60	284.00	144.0	125.4	134.2	116.9	182.10		
1000	104.7	116.6	112.50	588.00	154.8	298.50	111.0	96.6	76.6	106.6	176.60 (170.6)	Ns	51.01
Plant height (cm)													
0	36.71	34.05	31.44	86.70	39.75	56.78	46.89	42.98	39.49	36.99	45.18		
500	43.09	42.13	43.73	95.24	59.32	69.34	49.21	46.73	46.48	44.61	53.99		
1000	40.84	49.54	44.73	110.3	54.68	70.87	41.69	41.66	33.85	42.12	53.03 (50.73)	Ns	25.77

Days to 1st sprout, had a high significant and positive relationship with 100% sprouting and 100% foliar leaf. While, negatively correlated with EI (100%), CVE (100%), leaf area, plant height and yield components with yield.

Days to 100% sprouting, had a highly significant and positive relationship with 100% foliar leaf. While, negatively correlated with CVE (100%), leaf area, plant height and yield.

Coefficient velocity of emergence (100%), in days differed

significantly at (p<0.01). The leaf area, plant height and yield, were highly significant and positively correlated.

Leaf area, differed significant at 1% probability level, among the accessions, with plant height and yield attributes, positively correlated.

Plant height, had a significant and positive relationship with yield components and yield.

Economic yield differed at 1% probability level among the accessions, with leaf area, plant height and yield components which gave a positive correlation, respectively.

Table 4 Cont'd: Fertilizer x Accessions interaction effects on, growth and rhizome yield traits of 10 Turmeric accessions at Abak

NPK Kg Hec^{-1}	29	30	34	37	38	39	45	52	60	222	Mean	F-LSD (p<0.05)	C.V%
Plant biomass (g) plant^{-1}													
0	52.50	48.20	43.40	290.70	74.30	277.90	103.3	93.60	88.70	55.80	112.80		
500	96.10	92.50	67.30	504.10	42.30	362.40	95.30	109.2	117.3	100.3	158.70		
1000	81.60	97.50	57.20	56.90	118.5	511.60	164.3	81.40	60.00	85.90	182.70 (151.4)	Ns	57.74
Plant biomass tonnes hectare^{-1}													
0	8.75	8.04	7.23	48.46	12.39	46.31	17.22	15.59	14.78	9.30	18.81		
500	16.03	15.42	11.22	84.02	7.04	60.40	15.89	18.21	19.55	16.72	26.45		
1000	13.60	16.25	9.53	94.83	19.76	85.27	27.39	13.56	10.00	14.32	30.45 (25.24)	Ns	57.74
Economic yield (g) plant^{-1}													
0	36.70	29.70	28.90	217.90	50.60	209.30	74.30	64.60	57.50	34.70	80.42		
500	69.50	65.80	52.50	425.10	32.50	275.40	77.20	79.40	77.20	50.90	120.60		
1000	65.00	80.30	49.90	48.22	86.60	348.60	98.30	61.30	51.20	54.80	94.42 (98.48)	114.8***	58.60
Economic yield metric tonnes hectare^{-1}													
0	6.12	4.95	4.82	36.31	8.43	34.88	12.39	10.76	9.59	5.79	13.40		
500	11.58	10.97	8.75	70.85	5.42	45.90	12.87	13.24	12.87	8.48	20.09		
1000	10.84	13.38	8.31	80.36	14.43	58.10	16.39	10.21	8.53	9.14	24.32 (19.27)	19.13***	58.60
Harvest index													
0	0.69	0.64	0.71	0.72	0.67	0.75	0.67	0.62	0.53	0.62	0.66		
500	0.73	0.74	0.78	0.85	0.80	0.74	0.81	0.77	0.71	0.58	0.75		
1000	0.82	0.83	0.88	0.85	0.73	0.67	0.65	0.79	0.86	0.69	0.78 (0.73)	Ns	14.10

Note: Data in Parenthesis () = Grand Mean, **, *** Significant @ 5% and 1% Levels of Probabilities, ns – not significant. NCL= Nigeria Curcuma longa accession number, was named by the National Root Crop Research Institute (NRCRI), Umudike. IBF = Ibadan Finger.

Table 5: Linear correlation matrix on seedling emergence, growth and yield characters of Turmeric accessions at Abak

TRAITS	100% Sprout	EI 100%	CVE 100%	TC	LA	PHT (cm)	PBIO g PLT^{-1}	PBIO T HA^{-1}	YIELD g PT^{-1}	YIELD T HA^{-1}	HI
100% Sprout	1	.112	-.952*	-.026	-.718**	-.697**	-.620**	-.620**	-.633**	-.633**	-.104
EI 100%		1	.097	-.188	.043	-.035	.068	.068	.054	.054	.126
CVE 100%			1	-.029	.789**	.716**	.668**	.668**	.684**	.684**	.157
TC				1	-.011	.066	-.061	-.061	-.067	-.067	.090
LA					1	.839**	.815**	.815**	.848**	.848**	.227
PHT (cm)						1	.803**	.803**	.822**	.822**	.211
PBIO g PLT^{-1}							1	1.000**	.988**	.988**	.127
PBIO T HA^{-1}								1	.988**	.988**	.127
YIELD g PT^{-1}									1	1.000**	.227
YIELD T HA^{-1}										1	.227
HI											1

Traits(TR) - A= 100% Sprouting, B(EI)= Emergence interval 100%, C(CVE)= Coefficient velocity of emergence 100%, D(TC)= Tiller count clumps^{-1}, E(LA)= Leaf area (cm^{2}), F(PHT) Plant height (cm), G(PBioPLT^{-1}) = Plant biomass (g) plant^{-1}, H (PBio-T HA^{-1}) = Plant biomass (mtons) hec^{-1}, I(YPLT^{-1}) = Yield (g) plant^{-1}, J (YTHA^{-1}) = Yield (mtons) hec^{-1}, K(HI)= Harvest index. *, ** = Significant @ 1% and 5.

3.2. Discussion

3.2.1. Soil physico - chemical properties

The soil parent material and continuous intensive cultivation, influence the properties of soils. The region is characterized with low native soil fertility, with high rainfall > 1000 mm yr^{-1}. Also, the associated land degradation challenges, have made soil fertility management focus on reducing the leaching of basic nutrients in the soil through split application of inputs. A fertile soil is an important natural resource for crop productivity. Turmeric being a medicinal plant requires inputs for high yield (Akamine *et al.,* 2007). As soils vary from place to place, at times within a very short distance, different soil extraction methods are needed in order to correctly assess the soil nutrients availability for plants utilization. In developing world farmers are given blanket recommendation which is not in consonance with crops' demand. In other regions, soil analysis is available, but its cost and adaptability to crop needs is not precise enough (Noor *et al.,* 2014).

The study shows that the soils condition recorded strong acidic pH (KCl) condition of 3.60 – 3.80, before planting and at harvest (3.60 - 4.60). However, the acidic condition implies that the availability of some nutrients may be hampered making it insoluble (fixed) for plant root uptake. The bulk density values, which range from 1.45 - 1.67 g cm^{-3}, posed no constraint for crop's productivity. This is within the critical level range of 1.34 - 1.69 g cm^{-3} for crop growth (Pam and Brain, 2007). The soils from the experimental site is characterized by moderate organic carbon which range from 9 - 17.40 g kg^{-1}. This could be due to ploughing back the vegetative cover and crop residues into the soil. A low to moderate total nitrogen of 0.70 – 1.12 g kg^{-1} was recorded. Available phosphorus range of 40.10 – 76.48 mg kg^{-1} was high. The soil was low in potassium (0.09 – 0.15 cmol kg^{-1} when analysed. The exchangeable K levels below (0.18 - 0.20 cmol kg^{-1} suggests that the plant response with the application of K fertilizer is possible, particularly where heavy removal of K by harvesting was done (Agboola and Obigbesan, 1974).

The effects of Nutrient rates of NPK and Accessions on growth and yield of Turmeric

Soils treated with ample doses of NPK maintained significant plant growth and yielded more than those with sub-optimal nutrients and non-fertilized control plots (Neeraja 2015). Liebig's law of minimum explained that 'the most limiting factor in crop productivity determines the extent of crop performance. Invariably, the addition of the most limiting element enhances more efficient utilization of the less limiting mineral element.

The study reveals that, growth attributes had significant mean values for tiller count $clump^{-1}$, leaf area, plant height etc, when 500 kg NPK ha^{-1} 20:10:10 was applied. This fertilizer rate contains 150 kg N + 60 kg P_2O_5 and 60 kg K_2O ha^{-1}. Likewise, the result obtained is similar statistically with higher dose of 1000 kg NPK ha^{-1}. The rate had the fertilizer combinations of 200 kg N + 100 kg P_2O_5 and 100 kg K_2O ha^{-1}. Jones, 2002 observed that excessive dose of applied mineral fertilizer in the soil creates osmotic imbalance at the plant root-soil zone. This may interfere with nutrient uptake by plants from possible volatilization losses and leaching, due to high rainfall on loose soil properties and high soil acidity.

Conversely, poor growth and yield development at the control plots, indicates that the soil's basic nutrients are inadequate and would not sustain Turmeric production without inputs. However, the yield from plots that received 500 and 1000 kg NPK ha^{-1} were statistically similar, and higher than the control (Ekwere *et al.,* 2014). Similar, work was done by Olojede *et al.* (2005) on NPK requirements of turmeric under high and low altitude agro - ecologies with four rates of NPK 15:15:15 fertilizer (0, 200, 400 and 600 kg ha^{-1}). He reported a significant increase in yield parameters on mother and primary rhizomes number as fertilizer rates increased. The highest yield response at 600 kg ha^{-1} was reported, which is similar statistically to either 200 or 400 kg ha^{-1}. Baiyeri, (2002) though worked on growth, yield and harvest index of 'Agbagba' plantain in the sub – humid derived savannah region, evaluated four rates of Urea –N (0, 224, 448, and 672 kg Nha^{-1}), with basal application of 200 kg P_2O_5 and 350 kg K_2O ha^{-1}. He reported that the application of N–fertilizer beyond 448 kg N ha^{-1} had no significant advantage in the study area. Neeraja (2015) reported that applications of 360:120:160 kg NPK ha^{-1} in mother rhizomes used as planting materials, recorded the highest nitrogen (188.70 kg ha^{-1}), phosphorus (58.20 kg ha^{-1}) and potassium (139.50 kg ha^{-1}) uptake. An estimate suggests nutrient uptake

ha^{-1} of 120 – 170 kg N, 60 – 90 kg P_2O_5 and 110 – 300 kg K_2O ha^{-1} for yield of 30 - 40 tons' ha^{-1}. Banwasi and Singh (2010) reported that, application of phosphorus at 150 and 100 kg P_2O_5 ha^{-1} resulted in a significant vegetative growth with higher rhizome yield of turmeric. When P is limiting, the most striking effects are a reduction in leaf surface area, leading to fewer roots mass to reach water and nutrients. This leads to a decrease in the shoot-root dry weight ratio.

Akamine *et al.* (2007) observed that, the nutrient quality of 60 kg K_2O ha^{-1} recorded the highest content of curcumin, followed by 90 kg K_2O ha^{-1} and 120 kg K_2O ha^{-1}. However, higher doses of K_2O (150 and 180 kg ha^{-1}) was observed to reduce the curcumin content. It was further observed that the highest essential oil content (3.19 %) was recorded in the treatment combinations of 120 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. The utilisation of NPK nutrient uptake on growth and yield parameters of turmeric differed significantly with increasing application rates

4.0. Conclusion

Turmeric accessions - NCL 29, 30, 37, 39 and IBF 222, showed early potentials to sprouting uniformity, which ensured uniform field growth and maturity period at harvest. The initial rhizome weight, plant biomass, yield components and yield, with positive correlative relationship serve as good harvest yield index. Suistainable Turmeric production (leaf and rhizome) can be improve in low soil fertility status of Nigerian coastal rainforest soil, with Nutrient rate of 150kg N, 50kg P_2O_5, and 50kg K_2O (24.36 tons' ha^{-1}), over the control (13.92 tons' ha^{-1}). Therefore, for better Turmeric rhizome quality and optimum productivity, nutrient rate from 500 kg NPK 20:10:10 ha^{-1} is adequate and cost effective for farmers in Nigeria

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