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GROWTH AND YIELD INDICES OF CASSAVA (MANIHOT UTILISSIMA) AND SOIL PHYSICO-CHEMICAL PROPERTIES AS INFLUENCED BY DIFFERENT TRADITIONAL TILLAGE PRACTICES IN A HUMID ENVIRONMENT

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ABSTRACT

The experiment was carried out to evaluate the effects of traditional tillage practices namely No-till, Ridge-till and Mound-till, on cassava growth parameters and soil physico-chemical properties. It was a factorial experiment in a randomised complete block design replicated 3-times. The factors were the 3-tillage methods and cassava plant as a test crop. Data collected on soil properties include the particle size distribution, soil bulk density, soil water content, hydraulic conductivity, soil pH, soil organic carbon, total nitrogen, available phosphorus and exchangeable bases, while data collected on plant growth and yield indices include; plant height, stem girth, number of leaves, number of tubers, tuber length and weight of tubers. The data were collected at 2, 4, 6, 8, 10 and 12 months but cumulated at 12 months after planting. The data were subjected to analysis of variance and relationship between cassava tuber yield and some soil properties measured. Results of the study indicated that there was no significant difference between Ridge and Mound-till. The Ridge-till and Mound-till systems significantly influenced growth parameters and total yield of cassava than No-till system, hence were recommended of increased yield of cassava in the study area.

Keywords: Tillage Practices, Cassava, Soil Properties

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1. INTRODUCTION

Traditional tillage practices such as Flat-tillage (No-tillage), Ridge-tillage and Mound-tillage are well known among the rural agricultural communities either as a soil management practice to improve soil quality and productivity or increase crop yields especially the root and tuber crops (Obiefuna (2012)). In the humid environment,

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the soils are very fragile and low in inherent fertility and highly susceptible to soil erosion and different climatic hazards (A. A. Agboola et al. (1997)). Because of their fragile nature, various tillage practices as soil management options have been used from time immemorial. These include Flat-tillage (zero tilled), Ridge-tillage and Mound-tillage which consist essentially of heaping the surface soil mainly for root and tuber crops (Ogban et al. (2006)). The purpose of these tillage techniques is either to improve rainwater infiltration, conserve moisture, control weeds and most importantly increase yield quality (Acquaah (2006)). According to Agboola (1975), "no matter how simple these practices would be in the low-input agro-ecosystem", they are known to be low in organic matter due to lack of organic residues. Hullugalle et al. (1987) have observed that tillage has the tendency to reduce soil bulk density, and influence soil water infiltration rate.

Various studies on the influence of tillage practices as a land use system have shown both positive and negative influences. On the positive effect, Ogban et al. (2006) have stated that water infiltration, weeds and pests control are among the benefits. Lal (1975), observed that soil infiltration capacity, sorptive and transmissivity functions of soils, aggregate stability, water storage capacity and improved crop yield are all facilitated by tillage practices. Brady and Weil (2013) reported that soil bulk density is reasonably reduced in tilled soil. On the negative aspects, Acquaah (1996) opined that tillage practices have the tendency to cause soil compaction and create impervious soil barrier called pan which can restrict crop root growth and development. On his own contribution, Fasina et al. (2006) opined that tillage practices can either be used to conserve soils or expose them to erosion by creating water path-ways and subsequent loss of nutrients. Obieze (2013) reported that tillage practices can induce high run-off resulting in strong leaching of weatherable mineral reserves in the soil B-horizon.

The increasing importance of cassava as a major dietary food energy for majority of the urban and rural dwellers in the humid environment, and its contribution to national economies, rural incomes and provision of employment for rural and unemployed women in Nigeria, necessitate that different tillage techniques be studied, and their effects on soil physico-chemical properties be made known. Hence, the objective of this study is to evaluate growth and yield indices and soil properties as influenced by different traditional tillage systems namely, No-till, Ridge-till and Mound-till methods.

2. MATERIALS AND METHODS

Description of the experimental site : The study was conducted in Ani-ngene at Ugbolu, in Oshimili North Local Government Area with Latitude 6^0 14N and Longitude 6^0 40'E. The area is located in a typical humid environment that is characterized by distinct wet and dry seasons. The rainy season usually begins in April/-May, and continues till October with a short break in August. The dry season starts in November and ends in March. The rainfall pattern is bimodal with an annual of 1,850 – 2,250 mm and a temperature of 32.8^{0}C (NIMET (2017)). The entire vegetation is that of secondary vegetation with shrubs grasses and hedges dominating. Trees of different species are also found at the bank of major rivers that surround the area. The topography is gently undulating coastal plain soils and classified as Oxisols (Egbuchua (2014)). The entire soil area is characterized by high soil erodibility associated with high rainfall nature of the environment. Land use is entirely based on rain-fed agriculture and typical crops cultivated include yam, cassava, sweet potatoes, vegetables and cereals. The soil environment is seasonally flooded.

Field methods/Experimental design : The field experimentation was done during the 2017/18 farming season. A total land area of 0.35 ha was cleared manually and a space of 16 m $\times$ 16 m mapped out into blocks measuring 16 m $\times$ 12 m while sub-plots were 2 m $\times$ 2 m.

The ridges and mounds were manually made with the aid of locally fabricated hoe popularly known as 'ogu' (meaning local hoe). The ridges were made at 1.5 m apart, while mounds were made at 2 m apart and 45 cm high. The Flat-till was just cleared of weeds, shrubs and sedges with very minimal levelling. The field arrangement was a factorial experiment in randomized complete block design with three replicates. Different tillage systems were the factors The treatments were: No-tillage (Flat-till), Ridge Tillage and Mound tillage. The test crop was cassava (Manihot utilissima Var. TMS 130527).

Source of planting materials/planting : The planting materials were obtained from National Root and Tuber Research Institute Umudike, Nigeria. Planting was done in early June at the onset of the rainy season. The stems for planting were 25 cm long with 5-nodes each and planted at angle 45^0 slanting position 1 m $\times$ 1 m apart across the tillage methods (No-till, Ridge-till and Mound-till). Sprouting emerged at 4 weeks after planting (WAP) and individual blocks and sub-plots were regularly weeded manually and re-mounded as erosion tend to flattened them whenever the rain falls. Morphological growth data were collected at 2-months interval after planting (2, 4, 6, 6, 8, 10 and 12 months). The data collected included plant height using meter rule, stem girth using vernier calliper, number of leaves by counting, number of tubers at harvest by counting, weight of tubers/tuber yield by weighing using weighing balance. At harvest, root samples were collected from the middle rows and their length measured according to the grid intersection method (Tenant (1975)). Subsoil sampling was also carried out and analyzed routinely to determine the effects on soil physico-chemical properties in the inter-row spacing.

Laboratory studies : Collected soil samples at 0 – 30 cm depth from each of the plots were routinely processed by air-drying at room temperature of 25 – 27^{0}C, for 3-days, grinded using agape-mortar, and sieved with a 2 mm sieve mesh. Particle size distribution was determined by hydrometer method (Gee and Bauder (1986)). Bulk density was determined by oven-drying (S. A. Agboola (1979)). Insitu water content was determined 4 and 8 days after saturation by flooding an enclosed area of soil surface in each treatment (Agbenin (1996)). Infiltration runs were measured as recommended by Reynolds et al. (2002), while infiltration data assessed using Philip (1957) models as: $I = At + St^{1/2}$ where:

I = cumulative infiltration (cm)

S = soil water sorptivity,

A = transmissivity

t = time elapsed.

This was analyzed to estimate the sorptivity and transmissivity parameters.

Soil pH was determined in a 1:1 soil/water ratio using pH meter. Organic carbon (SOC) was estimated by Walkley-Black dichromate wet oxidation method (Nelson and Sommers (1982)). Total nitrogen was determined by micro-kjeldahl technique as described by Agbenin (1996). Available phosphorus was determined by Bray No 1 acid fluoride method. Exchangeable bases (Ca, Mg, K and Na) were determined using NH_4OAC saturation method and calcium and magnesium in solution read on an Atomic Absorption Spectrophotometer (AAS), while K and Na read on a flame emission photometer. Cation exchange capacity (CEC) was determined by neutral (pH 7.0) NH_4OAC saturation method (Agbenin, 1996).

Data analysis : The data obtained were subjected to the analysis of variance (ANOVA), and differences between means were separated using Duncan Multiple Range Test (DRMT). Correlation matrix (r) was also determined to know the relationship between some soil properties, tillage practices and yield of cassava.

3. RESULTS AND DISCUSSION

Initial physico-chemical properties

The results of the initial physico-chemical properties of the soil (Table 1) showed that the soil was sandy loam in texture with dominant sand fraction of over 70% and low clay content (19%). The pH of the soils with a mean value of 5.4 showed strong acid reaction. This could be attributed to soil erosion effect in the environment. The organic carbon, total nitrogen, and available phosphorus with these mean values: 18.87 gkg^{-1}, 0.76 gkg^{-1} and 5.38 gkg^{-1} respectively were all considered to be low. Exchangeable bases (Ca, Mg, K and Na) were also low depicting the 1:1 clay mineralogy and low base status of the soil. The initial bulk density value of 1.35 gcm^{-3} and infiltration rate of 52.54 cm/hr were all low except infiltration rate which was moderate due to some physical attributes of the soil.

The dominant sandy loam texture could be traced to the sandy nature of the parent material which is of sandstone origin. The overall bulk densities obtained in the tillage system were within the range of 0.94 – 1.40 gcm^{-3} described as ideal for crop growth in tropical soils (Brady and Weil (2013)). The sandy loam texture which has more sand than silt and clay may have caused the high rate of internal drainage which contributed to lower soil water content (Brady and Weil (2013)).

The higher values associated with tilled systems could be attributed to pore- size characteristics (macro-pores) and soil loosening (Landon (1991)) attributed high hydraulic conductivities associated with Ridge and Mound till to improvement and maintenance of pores spaces in the soil.

Table 1 **Initialphysico-chemical properties of the soil at planting (0 30 cm soil depth)**

Soil parameters	Mean values
Particle size distribution (%)	
Sand	71
Silt	10
Clay	19
Texture	Sandy loam
pH (H_2O)	5.7
Organic carbon (gkg^{-1})	18.87
Total nitrogen (gkg^{-1})	0.76
Available phosphorus	5.38
Exchangeable bases ($cmolkg^{-1}$)	
Ca	3.25
Mg	0.86
K	0.15
Na	0.03
CEC	7.5
Bulk density (gcm^{-3})	1.35
Infiltration rate (cm/hr)	52.54

Response of soil physical properties to different tillage systems

The response of soil physical properties to different tillage system is shown in table 2 . The dominant particle size fraction was sand with mean value of 71% sand in all the tillage methods evaluated. The bulk density of No-till, Ridge-till and Mound-till was not significantly different ($P \leq 0.05$) before cultivation but relatively increased in Ridge and Mound-tillage (1.30 gcm^{-3} and 1.95 gcm^{-3}) respectively while the value for No-till system was 0.35 gcm^{-3}. The higher bulk densities associated with the tilled system could be attributed to soil compaction resulting from the tillage practice (Table 2). Soil water contents was significantly lower in No-till practice with a value of 49.52% but gradually increased in Ridge-till (58.47) and Mound-till (62.14) respectively. This could not be unconnected to soil water properties, especially bulk density and soil pore spaces.

Hydraulic conductivity (Ks) was higher in Ridge and Mound-till than in No-till system (12.85 cm/hr and 10.84 cm/hr) respectively in Mound and Ridge-till compared to 7.3 cm/hr in No-till system.

Tillage (Ridge and Mound) significantly affected soil water sorptivity and transmissivity (Table 3). Sorptivity values were significantly higher in No-till system 5.45 compared to 3.32 and 3.52 obtained in Ridge till and Mound till respectively (Table 3

).

The higher sorptivity may be due to the absence of crusting and presence of micro-pores. Transmissivity values were also higher in No-till system (1.25(k) than in other tillage systems indicating that sorption and gravity were dominant (Fasina et al. (2006)).

Table 2 Response of soil physical properties to different tillage system

Treatment	Particle size distribution (%)			Text	B^d	SWC	Hydraulic conductivity cm/hr
	Sand →	Silt (%)	Clay ←				
NT	71^a	10^a	19^a	SL	0.95^b	49.52^c	7.3^c
RT	71^a	10^a	19^a	SL	1.30^a	58.47^b	10.84^b
MT	71^a	10^a	19^a	SL	1.35^a	62.14^a	12.85^a

Means with the same letters under the same column are not significantly different at $P \leq 0.05$ using Duncan Multiple Range Test (DMRT)
NT = No-till, RT = Ridge-till, MT = Mound-till, B^d = bulk density, SWC = soil water content.

Table 3 Effect of different tillage systems on the sorptivity and transmissivity of the cultivated soil

Treatment	Sorptivity (s)	Transmissivity (kA)
NT	5.45^a	1.25^a
RT	3.32^b	1.06^b
MT	3.52^b	1.03^b

Means followed by the same alphabets are not significantly different at $P < 0.05$ using Duncan Multiple Range Test (DRMT).
NT = No-till, RT = Ridge-till, MT = Mound-till

Response of soil chemical properties to different tillage systems

The response of soil chemical properties to different tillage systems is shown in Table 4. The soil pH across the tillage systems remained strongly acidic (5.32 – 5.52) (Table 4). Organic carbon contents significantly affected in No-till (18.20 gkg^{-1}) compared to 12.30 gkg^{-1} and 12.45 gkg^{-1} respectively for Ridge-till and Mound-till. Total nitrogen and available phosphorus which are soil organic matter dependent were lower at harvest 0.88 gkg^{-1}, 0.76 gkg^{-1} for tilled plots but slightly higher with No-tilled plots due to organic carbon status of the plots (1.25 gkg^{-1}). The total exchangeable bases (Ca, Mg, K and Na) across the tillage system were generally low prior to planting and at harvest. The low exchangeable cations could be attributed to 1:1 clay mineral status, and the depleting effects of soil erosion and leaching. The cation exchange capacity (CEC) were seemingly very low across the tillage system thereby reflecting the low base status of the environment (Table 4).

The soil organic carbon values were generally low and below 20 gkg^{-1} established by Federal Ministry of Agriculture and Natural Resources, (2010) for ecological zone. Generally total nitrogen across the tillage system was generally below1.5 gkg^{-1} assumed to be adequate for crop production in the environment (FMANR (2010)). Available Phosphorus was also low across the tillage system 5.24 $mgkg^{-1}$, 3.12 $mgkg^{-1}$ and 3.18 $mgkg^{-1}$ respectively. These values were lower than the established critical value of 8 $mgkg^{-1}$ for the ecological zone. The general low status of N.P.K could be attributed to effects of high rainfall in the environment and high acidic soil reaction. Low phosphorus is attributed to P-fixation process in the soil environment (Egbuchua (2014)).

Table 4 Response of soil chemical properties to different tillage systems

Treatment	Soil pH(H_2O)	O.C(gkg^{-})	Total N(gkg^{-1})	Avail. P($mgkg^{-1}$)	Ca	Mg	K	Na	CEC($cmolkg^{-1}$)
NT	5.25^a	18.20^a	0.76^a	5.38^a	1.45^a	1.12^a	0.15^c	0.03^c	9.45
RT	5.45^a	12.30^a	0.54^{ab}	3.12^{ab}	0.96^a	0.85^a	0.12^c	0.03^c	7.86
MT	5.32^a	12.45^a	0.58^{ab}	3.18^{ab}	0.92^a	0.88^a	0.10^c	0.03^c	7.82

Means with the same letters under the same column are not significantly different at $P \leq 0.05$ using Duncan Multiple Range Test (DMRT)
NT = No-till, RT = Ridge-till, MT = Mound-till, O.C. = Organic carbon

Effects of different tillage systems on morphological plant growth parameters

The effects of different tillage systems on morphological plant growth parameters are shown in Table 5. There were no significant difference ($P \leq 0.05$) in the Ridge-till and Mound-till systems (165.24 cm and 162.85 cm) but significant difference was observed ($P \geq 0.01$) with the No-till system (100.32 cm) (Table 5). Stem girth and number of leaves also followed the same trend.

The effects of different tillage practices on morphological plant growth parameters observed could be attributed to restricted land area of No-till to exhaust nutrients unlike the Ridge and Mound-tillage that have unrestricted soil area for root penetration and proliferation in the soil (Lal (1993)).

Table 5 Effects of different tillage system on morphological growth parameters at 12months after planting (MAP)

Treatment	Plant height (cm)	Stem girth (cm)	No of leaves
NT	103.32^b	3.02^b	58^b
RT	165.24^a	3.18^a	96^a
MT	162.85^a	3.15^a	92^a

Means followed by the same alphabets are not significantly different at $P \leq 0.05$ using Duncan Multiple Range Test (DRMT).
NT = No-till, RT = Ridge-till, MT = Mound-till

Effects of different tillage systems on yield at 12 months after planting

hows the yield of cassava at 12 months after planting. Number of tubers, tuber length, weight of tubers and tuber yield were all influenced at harvest by the treatments. Number of tubers and tuber length were significantly different 4.50 and 22.40 cm in No-till treatment compared to 2.12 and 2.15 cm with Ridge and Mound-till respectively (Table 6). However, weight of tubers and tuber yield were significantly different 18.35 kg/ha (Ridge-till) 17.28 kg/ha (Mound-till) compared to 12.52 kg/ha for No-till system.

With respect to tuber yield, Ridge-till performed better than Mound-till 26.6 kg/ha to 24.8 kg/ha although not statistically different ($P \leq 0.05$). No-till system had the least weight of tubers 12.52 kg/ha and total tuber yield 18.74kg/ha respectively. Okafor et al. (2013), reported similar trend in tuber yield indices in which Ridge-till and Mound-till performed better due to accumulated storage capacity of tilled soils. Dikko et al. (2014) however attributed the better performance to unrestricted influence of cultivated crops in exploring nutrients from the surrounding soil area as exemplified by the relationship between cassava tubers and some soil properties (Table 6).

Table 6 Effects of different tillage systems on total tuber length, number of tubers, weight of tubers and yield of tubers at 12 months after planting (MAP)

Treatment	Length of tubers (cm)	Number of tubers	Weight of tubers (kg/ha)	Yield of tubers (kg/ha)
NT	22.40^{a}	4.50^{a}	12.50^{b}	18.74^{a}
RT	20.10^{a}	2.12^{b}	18.50^{a}	26.63^{ab}
MT	18.54^{b}	2.15^{b}	17.20^{ab}	24.82^{ab}

Means with the same letters under the same column are not significantly different at $P \leq 0.05$ using Duncan Multiple Range Test (DMRT)

NT = No-till, RT = Ridge-till, MT = Mound-till

Correlation between soil properties, tillage systems and tuber yield of cassava.

hows correlation matrix among some selected soil properties and tillage system. The results showed high correlation between soil bulk density, Ridge-tillage ($r = 0.724^{**}$), Mound-till ($r = 0.745$) and yield ($r = 0.652^{*}$). Also, soil organic carbon has positive correlation with total nitrogen (0.826^{***}), exchangeable potassium ($r = 724^{**}$) and cassava tuber yield ($r = 0.778^{**}$). Similarly, Ridge-tillage and Mound-tillage also correlated positively with yield. The significant correlation ($P \leq 0.05$ or 0.01) between soil properties and yield of cassava was an indication that their interaction affects at varying degrees could be responsible for the better performance of the cassava yield.

Bulk density was not significantly correlated with soil organic carbon ($r = 0.322$), and No-till system ($r = 0.352$) but significantly correlated with Ridge-till (0.724^{**}) and Mound-till ($r = 0.745^{**}$. This implied that lower bulk density will help to stabilize soil aggregate, alleviate soil compaction and improve soil infiltration and transmission properties (Grossman and Reinsch (2002)).

Table 7 Correlation coefficient (r) showing correlation among some related soil properties, tillage system and tuber yield

	B^d	**SWC**	**Hyd. Cond.**	**Ph**	**SOC**	**TN**	**Exch. K**	**N.T**	**R.T**	**M.T**	**Y**
B^d	-										
SWC	0.025	-									
Hyd. Cond.	0.324	0.524									
Ph	0.015	0.212	0.154	-							
SOC	-0.332	0.613	0.322	0.215	-						
TN	0.018	-0.112	0.145	0.314	0.826	-					
Exch. K	0.020	-0.135	0.178	0.45	0.724*	0.610	-				
NT	-0.352	0.243	0.244	0.015	0.665	0.545*	0.654*	-			
RT	0.724*	0.546*	0.658**	0.024	0.445	0.587*	0.684*	0.556*	-		
MT	0.745*	0.583*	0.688**	0.028	0.386	0.601*	0.688*	0.422	0.725**	-	
Yield	0.652*	0.642*	0.345	0.625*	0.778*	0.724	0.725	0.325	0.810**	0.832**	

* Significant at 0.1 levels of probability, ** Highly significant at 0.1 & 0.05 levels of probability
SOC = soil organic carbon, B^d = bulk density, TN = total nitrogen, Exch. K = Exchangeable potassium, N.T = No-tillage, R.T = Ridge-till, M.T = Mound-till, Y = tuber yield of cassava.

4. CONCLUSION AND RECOMMENDATION

The increasing relevance of cassava as major dietary food energy source for majority of rural and urban dwellers in the humid environment, and its contributions to national economies necessitated that different tillage systems should be studied with a view to enhancing its production while their effects on soil physico-chemical properties be indicated.

The present study showed that due to the erosive nature of the study area, Ridge-till and Mound-till are both efficient methods of increasing growth and yield of cassava at Ani-ngene in Oshimili North Local Government Area of Delta State and were recommended because of their ability to improve soil water storage capacity, enhance infiltration characteristics and stability in soil aggregates as well as control noxious weeds that can compete with cultivated crops.

5. CONFLICT OF INTEREST

The authors have declared that no competing interest exist.

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