Effects of Conservation Tillage Method, Phosphorus Level, and Variety on Soil Organic Carbon and Cowpea Performance at Minna in Nigeria’s Southern Guinea Savanna

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

The study was carried out at the Teaching and Research Farm of the Federal University of Technology Minna, Gidan Kwano Campus in Latitude 9° 41' N, Longitude 6° 31' E, and Altitude 258.5 m above sea level. This study was conducted across 2 seasons within the cropping season of 2017 to determine the effects of tillage method, phosphorus level, and cowpea variety on soil organic carbon and cowpea performance in Minna. The experiment was therefore a 3x3x3 factorial arrangement in a split-plot design with tillage methods (zero, reduced, and manual ridging) and cowpea varieties (IT93K-452-1, IT99K-573-1-1, and IT90K-277-2) forming the main plot while phosphorus levels (0 P kg ha^{-1}, 30 P kg ha^{-1}, and 60 P kg ha^{-1}) formed the sub-plot with 3 replicates. Results obtained revealed that soil organic carbon was not significantly affected by tillage method and phosphorus level alone, regardless of the planting season. Cowpea variety alone significantly affected organic carbon only in the late planting season. Zero tillage, 60 kg P ha^{-1}, and IT93K-452-1 produced the highest soil organic carbon content, respectively.

In the early season, N fixed was highest (0.98 g plant^{1}) when cowpea was fertilized with 60 Kg P ha^{-1} under zero tillage. The closest to this value (0.92 g plant^{-1}) was recorded in the late season when 60 kg P ha^{-1} was supplied to cowpea under manual tillage. Regardless of the planting season and varietal difference, cowpea recorded the highest N fixed when fertilized with 60 kg P ha^{-1}. Across varieties, cowpea fixed more N under zero tillage than the other tillage methods, especially in the early season. In the late season, only IT90K-277-2 fixed N (0.49 g plant^{-1}) under zero tillage that was statistically not different from the highest N fixed due to manual tillage of soil under the cultivation of IT93K-452-1 and IT99K-573-1-1 (0.62 g plant^{-1}, respectively). In the early season, IT99K-573-1-1 cultivated under zero tillage produced the highest grain yield (404.11 kg ha^{-1}). Fodder yield followed a different trend compared to grain yield. In the early planting season, cowpea fertilized with 60 kg P ha^{-1} produced the highest fodder yield, while in the late season, the application of 30 kg P ha^{-1} produced the highest fodder yield. Regardless of the planting season, grain yield was highest when IT99K-573-1-1 was fertilized with 60 kg P ha^{-1}. Averagely, soil organic carbon content, N fixed, and grain yield values were highest during the late planting than the early planting season. The reverse was, however, the case for fodder yield, seedling emergence, root length, root, and shoot biomass, respectively. For the best performance in cowpea production, farmers are encouraged to plant IT99K-573-1-1 on zero-tilled soil with phosphorus application at the rate of 60 kg ha^{-1}. IT90K-277-2, which is the most genetically stable variety across seasons, will be most ideal in controlling negative climate change and should therefore be considered for further investigations.

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Keywords: carbon, cowpea, organic, phosphorus, tillage, variety.

1. Introduction

Cowpea, (*Vigna unguiculata)* commonly called "beans," is a staple food across the globe and an important proteinous food crop that plays a vital role in most farming systems due to its ability to improve soil properties. Cowpea is a legume consumed in most parts of the developing countries of Africa, Asia, and South America as dry seed, fresh green pods, and forage (Barret, 1987). It is highly valued both for its grain for human consumption and forage for animal feed and therefore has a dual utility and is vital in maintaining food security, particularly in the tropics. Apart from its use as a food crop, cowpea is of vital importance to soil fertility improvement through biological nitrogen fixation (John *et al.,* 2014). Due to the importance of cowpea, research has led to the development of several cowpea varieties with varying crop performance, biological nitrogen-fixing abilities, and influence on soil physical and chemical properties. Sustainable agricultural production, however, is a holistic management of arable soil that deals with the complex, dynamic, and interrelated soil physical and chemical properties (Fowler *et al.,* 2001).

Appropriate crop variety, proper tillage practice, and adequate rate of phosphorus fertilization are therefore crucial to the improvement of these soil properties and the performance of cowpea. Tillage practices, which are a series of operations that manipulate soil in order to prepare good seed beds for crop production, are critical in improving soil physical properties, productivity, and crop yield (FAO 2006). Tillage methods include manual and mechanical tillage, which exposes the soil to various degrees of erosion and soil degradation, minimum tillage, and no tillage, which conserve the soil and minimize perturbation of the soil body (Moussa-Machraoui *et al.,* 2010).

In an attempt to curb the declining soil productivity caused by continuous tillage, farmers have resorted to fertilizer application to improve crop performance. With regard to cowpea production, phosphorus fertilizer is crucial to its growth and yield. Phosphorus plays a vital role in nodulation, biological nitrogen fixation, and yield of cowpea. Phosphorus is an important constituent of adenosine triphosphate (ADP), which provides the energy needed to drive most biochemical reactions within crops, thus influencing most physiological processes, such as photosynthesis and nodulation, which are crucial for biological nitrogen fixation and ultimately cowpea performance. However, it is predominantly deficient in most soils, and most local farmers place little emphasis on the application of phosphorus to the soil in cowpea cultivation (Ayodele and Oso, 2014). To this end, there is the need to apply an appropriate rate of phosphorus for improvement of soil chemical properties and optimum cowpea performance.

Information on the most appropriate combination of tillage method, cowpea variety, and appropriate rate of phosphorus fertilization that will improve soil organic carbon and performance of cowpea, particularly in Minna, is lacking. Therefore, this study was carried out to evaluate the effects of the aforementioned factors on soil organic carbon and cowpea performance in Minna, Nigeria. The aim of this study was to determine the effects of tillage method, phosphorus level, and cowpea variety on soil organic carbon and cowpea performance in Minna, Nigeria. The specific objectives were to:

i. evaluate the effects of tillage method, phosphorus level, and cowpea variety on soil organic carbon.
ii. estimate the effects of tillage method, phosphorus level, and cowpea variety on growth and biological nitrogen fixation.
iii. determine the effects of tillage method, phosphorus level, and cowpea variety on yield of cowpea.

2. Materials and Methods

2.1. Site Location and Characteristics

The study was carried out at the Teaching and Research Farm of the Federal University of Technology Minna, Gidan Kwano Campus (latitude 9° 41' N and longitude 6° 31' E; 258.5 m above sea level) during the cropping season of 2017. The climate of Minna is sub-humid, with a mean annual rainfall of about 1284 mm and a distinct dry season of about 5 months' duration occurring from November to March. The mean maximum temperature is uniformly high throughout the year, about 33.5^{o}C, particularly in March and June (Ojanuga, 2006), while the growing season starts from late May through early October. The physical features around Minna consist of gently undulating high plains developed on basement complex rocks made up of granite, migmatites, gneisses, and schists. Beneath the plains, the bedrock is deeply weathered and constitutes the major soil parent material (saprolite) (Ojanuga, 2006), while the soil is well-drained sandy loam. The study site lies within the southern Guinea savanna vegetation belt of Nigeria, and common crops grown on the site include maize, cowpea, yam, and groundnut.

2.2. Soil Properties

Soil samples were collected using a soil auger at 0-20 cm depth based on the simple random sampling plan before planting and after harvesting. The samples collected before planting were used to determine the initial soil physical and chemical properties. The samples were thoroughly mixed to obtain a composite sample, air-dried, and passed through a 2mm sieve in preparation for analysis according to standard methods as follows: soil texture by the hydrometer method (Bouyoucos, 1962), and textural class determined by using the textural triangle. Soil pH by pH meter in a 1:2.5 soil to water/$CaCl_2$ suspension, organic carbon by the wet oxidation method (Nelson and Sommers,1982), total nitrogen by the macro-kjeldahl method (Jackson, 1962), available phosphorus by the Bray–P1 method, exchangeable bases (Ca, Mg, Na, and K) by extraction with 1N ammonium acetate (NH_4OAC). Calcium (Ca) and magnesium (Mg) were by the EDTA titration method, while sodium (Na) and potassium (K) were determined by the flame photometry (Jackson, 1962). Exchangeable acidity was determined titrimetrically with NaOH as described by Udo*et al.* (2009), and effective cation exchange capacity (ECEC) was calculated as the summation of total exchangeable bases plus exchangeable acidity (Udo *et al.*, 2009). Soil samples collected after harvest were used to determine soil organic matter as affected by treatments.

2.3. Treatments and Experimental Design

The experiment was a 3x3x3 factorial arrangement in a split plot design with tillage methods (zero, reduced, and manual ridging) and cowpea varieties (IT93K-452-1, IT99K-573-1, and IT90K-277-2) forming the main plots, while phosphorus levels (0 kg/ha, 30 kg/ha, and 60 kg/ha) formed the sub-plots, with 3 replicates. A total of 81 plots were used, each measuring 3×4 m, with 1 m between blocks and 1 m between plots within a block, and 2 m between replicates. For zero and reduced tillage practices, growing weeds were killed with paraquat two days before planting, and the chemically killed weeds, along with surviving weed residue from the previous season, were preserved as soil cover. The zero tillage plots were not subjected to any mechanical soil disturbance apart from the digging of shallow holes for seed placement during sowing. On the reduced tillage plots, the planting lines were ripped with a hoe to a depth of 15-20 cm and a width of 15 cm, without destroying the soil cover on the interrow spaces. The ridged tillage plots were ridged with a bigger hoe, burying the soil cover in the process. The three levels of phosphorus were applied in the form of single superphosphate using the ring method of application. Two crops of cowpea were cultivated sequentially. The characteristics of the three white-seeded cowpea varieties evaluated in this study are briefly described below (Ajeigbe *et al.*, 2010; Ewansiha *et al.*, 2015):

IT99K-573-1-1

Early maturity (70-79 days), white seed coat texture, semi-erect growth habit, multiple disease resistance especially wilt, Striga and Alectra resistance, high fodder and grain yield

IT90K-277-2

Medium maturity (75-80 days), medium-sized seeds, some level of resistance to insects and diseases, needs 2-3 sprays, high fodder yield, high grain yield about 1500 – 2000 kg ha^{-1}

IT93K-452-1

Extra-early maturity (60-69 days), white seed coat texture, erect growth habit, small seed size, resistance to insects and diseases, high fodder yield, 1200 grain yield (kg ha^{-1}), good for double cropping.

2.4. Cultural Practices

The cowpea seeds obtained from the Institute of Agricultural Research (IAR), Amadu Bello University, Zaria were sown at the rate of 3 seeds per hole at a depth of 2-3 cm and spacing of 50 cm between rows and 20 cm within rows. Thinning was done eight days after emergence to allow only two seedlings per stand. Early planting was done on 2nd July, 2018, while late planting was done on 6th October, 2018. Nitrogen was applied to all plots at the rate of 20 kg/ha in the form of urea two weeks after planting at a 5 cm depth and 5 cm away from the planting line using the side placement method. Regular weeding was done by hand pulling and by using a hoe. During the vegetative, flowering, and pod-filling stages, an insecticide, termispring (chlorpyriphos 20%EC), was applied as a foliar spray as soon as insects were noticed using 15-litre knapsack sprayer. Harvesting was done by hand picking when the pods were physiologically matured and then sun-dried for 3 days.

2.5. Soil and Crop Parameters

2.5.1. Determination of Soil Organic Carbon

Air-dried soil samples were ground to pass through a 0.5 mm mesh sieve and placed in an Erlenmeyer flask. Then 10 ml of 1N potassium dichromate ($K_2Cr_2O_7$) and 20 ml of concentrated sulfuric acid (H_2SO_4) were added to 0.5g of soil while stirring it to ensure good mixing of the soil with the reagent before allowing it to rest for 30 minutes. Thereafter, 200 ml of distilled water, 10 ml of concentrated H_3PO_4, and 1 ml of 0.16% diphenylamine indicator were added in that order. The excess dichromate that was not reduced in the reaction was determined by volumetric titration using ammonium ferrous sulphate (Mohr's salt) and titrating with 0.4 N

$FeSO_4$ to a greenish color endpoint which later changed to dark green. Thereafter, the ferrous sulfate was added drop by drop until the color changed sharply from blue-green to reddish-grey. The soil organic carbon was then determined using the procedure illustrated by McLeods (1973).

Calculations

From the equation of the reaction,

$2Cr_2O_7^{2-} + 3C + 16H^+ \rightarrow 4Cr^{3+} + 8H_2O + 3CO_2\uparrow$

1 ml of 1 N Dichromate solution is equivalent to 3 mg of carbon.

Where the quality and normality of the acid/dichromate mixture used are as stated in the method, the percentage of carbon is determined from the following:

$$\text{Organic carbon} = \frac{0.003g \times N \times 10ml \times (1 - T/S)}{.\,ODW} \times 100$$

Where: N = Normality of $K_2Cr_2O_7$ solution, T = Volume of $FeSO_4$ used in sample titration (ml), S = Volume of $FeSO_4$ used in blank titration (ml), ODW = Oven-dry sample weight (g)

2.5.2. Seedling emergence

To determine seedling emergence, the number of germinated seedlings in each plot was counted and recorded before thinning. With the equation below, the seedling emergence percentage was calculated.

$$\text{Seedling emergence \%} = \frac{\text{Number of germinated seedlings}}{\text{Total number of seeds planted}} \times 100$$

2.5.3. Root depth

At 50% flowering, four crops were randomly selected from each plot, and the upper parts of the plants were cut off. The crops were carefully dug up and washed. The plant roots were then placed on a board, and with a standardized measuring meter, the maximum length of the roots was measured as root depth.

2.5.4. Root and shoot biomass

To determine the root biomass, the crops used in determining the root depth were also used for determining the root biomass after the nodules had been removed. The roots were put in envelopes and oven-dried at 70^0C for 48 hours and weighed. The values were recorded as root biomass.

2.5.5. Number of nodules and nodule dry weight

For nodulation assessment, four crops were dug up from each plot. The root nodules were removed and manually counted to ascertain the number of nodules prior to determination of nodule dry weight, which involved oven drying at 70^0C to a constant weight for 48 hours. Weighing was done using a sensitive weighing machine calibrated in grammes.

2.5.6. Nitrogen fixed and percentage nitrogen derived from the atmosphere (%Ndfa)

At 50% flowering, four crops were randomly selected from each plot, and the upper parts of the plants were cut off and used for determination of nitrogen fixed. The samples were oven-dried to a constant weight at 70^{o}C for 48 hours, then chopped into smaller bits with a knife. The samples were then thoroughly mixed by hand, and a subsample weighing 10 g was taken and finely ground using a laboratory ring grinder. The finely ground sample was then digested. Thereafter, 10 ml of water was gradually added to the digest, and the diluted digest was transferred to a volumetric flask using a glass funnel. Distilled water was added to wash down all traces of the digest into the flask. Distilled water was again added to the flask to make it up to the mark and then distilled. After distillation, 85 ml of the distillate was immediately titrated with standard HCl until the indicator reached the grey–red end point. The titration volume was recorded, and one more drop of the indicator was added, and the indicator turned a pink-red colour. To calculate the amount of nitrogen fixed, the equation below was used.

$$\text{BNF} = \frac{\text{Normality of standard HCl} \times 0.5 \times \text{titration (ml)}}{0.03571}$$

The Total Nitrogen Difference (TND) technique (Huaser 1992; Giller 1992) was used in estimating the amount of biological nitrogen fixed by cowpea. This was calculated with the equation below.

$$\text{BNF} = N_{\text{shoot leg}} - N_{\text{shoot ref}}$$

Where $N_{\text{shoot leg.}}$ = Amount of nitrogen in the shoot per legume plant (N uptake in g plant^{-1}) and $N_{\text{shoot ref}}$ = Amount of nitrogen in the shoot per reference maize (N uptake in g plant^{-1}).

To estimate the percentage nitrogen derived from the atmosphere (%Ndfa), the equation below was used:

$$\%\text{Ndfa} = \frac{100(\text{N fixed})}{N_{\text{shoot leg}}}$$

Where, N fixed = Nitrogen fixed in the soil and $N_{\text{shoot leg.}}$ = Amount of nitrogen in the shoot per legume plant (N uptake in g plant^{-1})

2.5.7. Fodder and Grain Yield

After harvest, the fodder from the net plot was cut off, rolled up, and oven-dried to a constant weight, then weighed to obtain the fodder yield in kg/ha. For the grain yield, grains harvested from the net plot were weighed, and the grain yield was recorded in kg/ha.

2.5.8. Statistical Analysis

Data collected were subjected to statistical analysis using MINITAB version 17.0, 2015 statistical package. Analysis of variance (ANOVA) of the general linear model was used to check for significant effects, and significant means were separated using the Fisher pairwise comparisons method.

3. Results and Discussions

Table 1. Initial Soil Physical and Chemical Properties

Soil properties	Value
Sand (g kg^{-1})	825
Silt (g kg^{-1})	70
Clay (g kg^{-1})	105
Textural class	Sandy loam
pH (H_2O)	6.6
pH ($CaCl_2$)	5.0
Organic carbon (g kg^{-1})	4.1
Total nitrogen (g kg^{-1})	2.8
Available P (mg kg^{-1})	6.0
Exchangeable bases (cmol kg^{-1})	
Mg^{2+}	0.6
Ca^{2+}	1.7
K^{+}	0.2
Na^{+}	0.4
Exchangeable Acidity (cmol kg^{-1})	0.9
ECEC (cmol kg^{-1})	3.8

(Source: Researcher’s field work, 2017)

Table 2. Main Effects of Tillage, Phosphorus Level and Cowpea Variety on Soil Organic Carbon in 2017

	Early Planting Late Planting	
Treatment	SOC (g kg^{-1})	SOC (g kg^{-1})
Tillage (T)		
Zero	4.58[a]	6.48[a]
Reduced	4.27[b]	5.31[b]
Manual ridging	4.05[c]	4.23[c]
SE±	0.16	0.86
Phosphorus (P) (P_2O_5 ha^{-1})		
0 kg	3.80[c]	4.88[c]
30 kg	4.08[b]	5.01[b]
60 kg	4.17[a]	6.12[a]
SE±	0.16	0.17
Variety (V)		
IT93K-452-1	4.13[a]	4.37[a]
IT99K-573-1-1	4.09[a]	4.29[b]
IT90K-277-2	4.10[a]	4.33[ab]
SE±	0.16	0.19
Interaction		
T*P	NS	NS
V*P	NS	NS
T*V	NS	NS
T*V*P	NS	NS

*SOC = Soil organic carbon, * = Significant at P ≤ 0.05, NS = Not significant, Means with the same letter in a column for each factor are not significantly different (P ≤ 0.05)*

Table 3. Main effects of Tillage, Phosphorus Level and Variety on Seedling Emergence, Shoot Biomass, Root Depth and Root Biomass

Factor Level / Interaction	Early planting					Late planting			
	Seedling emergence (%)	Shoot biomass (g plant^{-1})	Root depth (cm)	Root biomass (g plant^{-1})		Seedling emergence (%)	Shoot biomass (g plant^{-1})	Root depth (cm)	Root biomass (g plant^{-1})
Tillage (T)									
Zero tillage	67.18^{b}	33.34^{a}	25.05^{b}	1.50^{b}		65.73^{a}	18.28^{a}	15.02^{b}	1.00^{a}
Reduced tillage	67.95^{a}	34.96^{a}	27.80^{b}	1.52^{b}		66.53^{a}	16.33^{b}	16.95^{b}	1.00^{a}
Manual tillage	68.35^{a}	33.34^{a}	29.93^{a}	1.90^{a}		66.29^{a}	14.78^{b}	24.82^{a}	1.04^{a}
SE±	2.06	1.89	1.52	1.17		2.48	1.82	1.61	0.03
Phosphorus (P)(P_2O_5 ha^{-1})									
0 kg	65.35^{a}	14.12^{c}	28.69^{a}	1.04^{b}		62.70^{b}	14.12^{a}	19.67^{a}	0.80^{a}
30 kg	65.5^{a}	33.89^{b}	27.21^{a}	1.92^{a}		65.06^{b}	15.94^{a}	18.03^{a}	1.11^{a}
60 kg	69.23^{a}	44.73^{a}	26.90^{a}	2.06^{a}		68.27^{a}	18.34^{a}	19.11^{a}	1.13^{a}
SE±	1.42	1.89	1.52	1.17		1.23	1.82	1.64	0.03
Variety (V)									
IT93K-452-1	59.27^{b}	33.75^{c}	25.97^{b}	1.56^{a}		57.55^{b}	15.66^{a}	17.11^{a}	0.78^{b}
IT99K-573-1-1	67.73^{a}	29.91^{b}	27.56^{a}	1.33^{a}		67.87^{a}	17.53^{a}	19.82^{a}	1.09^{a}
IT90K-277-2	66.48^{a}	37.42^{a}	29.25^{a}	2.12^{a}		65.78^{a}	18.21^{a}	19.86^{a}	1.97^{a}
SE±	2.06	1.89	1.52	1.17		2.48	1.82	1.61	0.05
Interactions									
T*P	NS	NS	NS	NS		NS	NS	NS	NS
V*P	NS	NS	NS	NS		NS	NS	NS	NS
T*V	NS	NS	NS	NS		NS	NS	NS	NS
T*V*P	NS	NS	NS	NS		NS	NS	NS	NS

Table 4. Main Effects of Phosphorus Level and Cowpea Variety on Number of Nodules, Nodule Weight, Nitrogen Fixed and %Ndfa

	Early Planting			Late Planting		
	Nodule Number ($Plant^{-1}$)	Nodule weight (g $Plant^{-1}$)	N fixed (g $Plant^{-1}$)	% Ndfa	N Fixed	% Ndfa
Tillage (T)						
Zero tillage	26.81[a]	1.11 [a]	0.49[a]	17.81	0.56[a]	20.16 [a]
Reduced tillage	24.68 [a]	0.49 [a]	0.39[b]	14.89	0.37[b]	19.30 [a]
Manual tillage	23.03 [a]	0.44 [a]	0.30[b]	14.50	0.36[b]	15.94 [a]
SE±	3.11	0.39	0.02	1.09	0.04	1.44
Phosphorus (P) (P_2O_5 ha^{-1})						
0 kg	15.51[b]	1.39 [a]	0.16[b]	8.85[b]	0.25[b]	15.83[b]
30 kg	28..51[a]	1.41 [a]	0.20[b]	9.15[b]	0.33[b]	12.81[b]
60 kg	30.51[a]	1.49 [a]	0.82[a]	9.19[a]	0.71[a]	26.77[a]
SE±	3.11	0.39	0.02	1.09	0.04	1.44
Variety (V)						
IT93K-452-1	20.51[b]	0.43 [a]	0.42 [a]	13.51[a]	0.45 [a]	20.44 [a]
IT99K-573-1-1	22.34[ab]	1.73 [a]	0.35 [a]	16.68[a]	0.43[\a]	16.70 [a]
IT90K-277-2	31.66[a]	1.46 [a]	0.42 [a]	17.01[b]	0.41[a]	18.27 [a]
SE±	3.11	0.39	0.02	1.09	0.04	1.44
Interactions						
T*P	NS	NS	*	NS	*	NS
V*P	NS	NS	*	NS	*	NS
T*V	NS	NS	*	NS	*	NS
T*V*P	NS	NS	NS	NS	NS	NS

N fixed=Nitrogen fixed. %Ndfa= % nitrogen derived from atmosphere, significance at p <_ 0.05 (*), not significant (NS), means with the same letter in a column for each factor are not significantly different (P > 0.05)

Table 5. Main effects of Tillage, Phosphorus Level and Variety on Fodder Yield and Grain Yield

Factor Level / Interaction	Early planting		Late Planting	
	Fodder Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Fodder Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})
Tillage (T)				
Zero tillage	2593.44^{a}	286.95^{a}	1205.46^{a}	310.94^{a}
Reduced tillage	2286.18^{a}	245.76^{b}	672.10^{b}	257.87^{b}
Manual tillage	1081.94^{b}	194.40^{b}	533.28^{b}	206.36^{b}
SE±	179.00	29.50	180.00	29.00
Phosphorus (P) (P_2O_5 ha^{-1})				
0 kg	1747.67^{b}	194.47^{b}	689.34^{b}	214.40^{b}
30 kg	2469.14^{a}	239.49^{a}	1031.74^{a}	253.16^{a}
60 kg	2655.75^{a}	293.15^{a}	689,76^{b}	304.60^{a}
SE+_	179.00	29.50	180.00	29.00
Variety (V)				
IT93K-452-1	2161.56^{b}	279.79^{b}	930.88^{a}	293.69^{a}
IT99K-573-1-1	1468.87^{c}	346.62^{a}	653.03^{b}	367.15^{a}
IT90K-277-2	3231,14^{a}	100.71^{c}	382.91^{c}	133.33^{b}
SE±	179.00	29.50	180.00	29.00
Interactions				
T*P	NS	NS	NS	NS
V*P	*	*	*	*
T*V	NS	*	NS	*
T*V*P	NS	NS	NS	NS

Table 6. Interaction Effects of Tillage and Phosphorus on Nitrogen Fixed (g plant- ^{1}) during the Early and Late Planting Seasons

	Early Planting				Late Planting		
Tillage Method	0 kg P_2O_5 ha^{-1}	30kg P_2O_5 ha^{-1}	60kg P_2O_5 ha^{-1}		0 kg P_2O_5 ha^{-1}	30kg P_2O_5 ha^{-1}	60kg P_2O_5 ha^{-1}
Zero	0.18^{c}	0.34^{b}	0.98^{a}		0.30^{b}	0.29^{b}	0.52 ^{ab}
Reduced	0.14^{cd}	0.13^{cd}	0.91^{a}		0.21^{b}	0.19^{bc}	0.72 ^{a}
Manual Ridging	0.10^{d}	0.14^{cd}	0.59 ^{ab}		0.49^{ab}	0.29 ^{b}	0.92 ^{a}
SE±		0.02				0.02	

Means with the same letter are not significantly different (P > 0.05)

Table 7. Interaction Effects of Variety and Phosphorus on Nitrogen Fixed (g plant-^{1}) during the Early and Late Planting Seasons

	Early	Planting Variety			Late	Planting Variety	
P Level P_2O_5 ha $^{-1}$	IT93K-452-1	IT99K-573-1-1	IT90K-277-2		IT93K-452-1	IT99K-573-1-1	IT90K-277-2
0 kg	0.17^{b}	0.17^{b}	0.16^{b}		0.31^{c}	0.45^{b}	0.23^{c}
30 kg	0.16^{b}	0.18^{b}	0.26^{b}		0.37^{c}	0.20^{c}	0.20^{c}
60 kg	0.94^{a}	0.71^{a}	0.84^{a}		0.68^{a}	0.65^{a}	0.82^{a}
SE±		0.01				0.01	

Means with the same letter are not significantly different (P > 0.05)

Table 8. Interaction Effects of Tillage and Variety on Nitrogen Fixed (g plant- ^{1}) during the Early and Late Planting Seasons

	Early	Planting Variety			Late	Planting Variety	
Tillage Method	IT93K-452-1	IT99K-573-1-1	IT90K-277-2		IT93K-452-1	IT99K-573-1-1	IT90K-277-2
Zero	0.38^{ab}	0.49^{a}	0.62^{a}		0.36^{b}	0.25^{c}	0.49^{ab}
Reduced	0.41^{ab}	0.41^{ab}	0.36^{ab}		0.38^{b}	0.43^{b}	0.31^{bc}
Manual	0.48^{a}	0.16^{c}	0.29^{c}		0.62^{a}	0.62^{a}	0.46^{b}
SE±		0.02				0.01	

Means with the same letter are not significantly different (P > 0.05)

Table 9. Interaction Effects of Variety and Phosphorus on Fodder Yield (kgha- ^{1}) during the Early and Late Planting Seasons

Phosphorus Level		Early Planting				Late Planting	
P_2O_5 ha^{-1}	IT93K-452-1	IT99K-573-1-1	IT90K-277-2		IT93K-452-1	IT99K-573-1-1	IT90K-277-2
0 kg	1641^{f}	1165^{h}	2437^{d}		678^{e}	686^{e}	704^{d}
30 kg	2345^{e}	1584^{g}	$347\ 9^{b}$		1615^{a}	631^{f}	850^{c}
60 kg	2499^{c}	1658^{f}	3777^{a}		500^{g}	643^{f}	927^{b}
SE±		26.11				26.19	

Means with the same letter are not significantly different (P = 0.05)

Table 10. Interaction Effects of Variety and Phosphorus on Grain Yield (kgha- ^{1}) during the Early and Late Planting Seasons

Phosphorus Level	Early Planting				Late Planting		
P_2O_5 ha^{-1}	IT93K-452-1	IT99K-573-1-1	IT90K-277-2		IT93K-452-1	IT99K-573-1-1	IT90K-277-2
0 kg	247.60^{d}	237.74^{d}	98.22^{e}		266.09^{d}	$274.\ 23^{d}$	112.09^{e}
30 kg	293.14^{c}	324.80^{b}	100.61^{e}		306.09^{c}	337.83^{b}	115.72^{e}
60 kg	298.72^{c}	477.31^{a}	103.40^{e}		312.20^{c}	489.44^{a}	112.35^{e}
SE±		26.11				29.15	

Means with the same letter are not significantly different (P = 0.05)

Table 11. Interaction Effects of Tillage and Variety on Grain Yield (kgha- [1]) during the Early and Late Planting Seasons

Tillage Method	Early Planting				Late Planting		
	IT93K-452-1	IT99K-573-1-1	IT90K-277-2		IT93K-452-1	IT99K-573-1-1	IT90K-277-2
Zero tillage	207.42^{f}	404.11^{a}	125.83^{e}		218.38^{e}	417.17^{a}	137.11^{f}
Reduced tillage	232.32^{d}	274.82^{c}	76.13^{a}		243.11^{d}	289.07^{c}	87.06^{h}
Manual tillage	399.71^{a}	361.05^{b}	100.33^{g}		422.32^{a}	394.70^{b}	115.95^{g}
SE±		20.21				22.11	

Means with the same letter are not significantly different (P > 0.05)

3.1. Initial Soil Physical and Chemical Properties

Textural class of the initial soil was sandy loam (Table 1), which is ideal for the multiplication of rhizobia. This is consistent with the work of Martyniuk and Oron (2008), who reported that light textured soils were found to be beneficial for the proliferation and survival of root nodule bacteria. Soil pH in H_20 (6.6) was slightly acidic, falling within the range of 5.5 to 7 reported to be optimum for the release of plant nutrients (Sharu *et al*., 2013). Soil organic carbon (4.1 g Kg^{-1}), available P (6 mg Kg^{-1}), and total nitrogen (2.8 g Kg^{-1}) were low according to Esu (1991)'s rating, and these are common features of savanna soils.

3.2. Soil and Crop Parameters as affected by Treatments

3.2.1. Soil organic carbon

Tillage method significantly affected soil organic carbon (Table 2). Soil organic carbon under zero tillage was significantly higher than the organic carbon content under manual ridged tillage**.** The difference observed could be because manual ridging loosens the soil and exposes the organic matter held within the soil, thereby accelerating decomposition and leading to lower soil organic carbon content as compared to zero tillage, where the organic matter has been left undisturbed. This is consistent with the finding of Moussa-Machraou *et al.* (2010) that tillage reduces soil organic carbon content. Phosphorus rates also had significant effects on soil organic carbon. The high organic carbon recorded at the 60 Kg P_20_5/ha phosphorus rate could be attributed to the high shoot and root biomass production that eventually returned to the soil as litter falls (Kang and Naggos, 1983). Cowpea variety had a significant effect on soil organic carbon only in the late planting season, which appears to be close to the ideal time for planting cowpea in Minna **(**Ezedinma, 1966).

3.2.2. Seedling Emergence and Root Depth

Tillage method did not have a significant effect on seedling emergence (Table 3). Among the tillage methods, the high seedling percentage emergence recorded in manual ridging in the early season could be attributed to the ease with which seedlings emerged via the loosened soil surface. Crop variety significantly affected seedling emergence (Table 3). The significantly lower percentage emergence observed in IT93K-452-1 compared to the other varieties during the early and late seasons could be due to its genetic stability across seasons.

Tillage method, phosphorus level, and variety did not significantly affect root depth, respectively, especially in the early season (Table 3). In the late season, however, only the tillage method significantly affected root depth (Table 3). Significantly higher root depth observed in manual ridging compared to other methods during the late planting period could be a result of the ease with which roots elongate and travel in loosened soil due to the tillage operations carried out. Root depth reduced with increase in phosphorus level, especially at the early planting season, indicating that the roots did not need to explore the soil far from the immediate root zone due to proximity and availability of phosphorus. Elongation of roots may be an indication of a search for phosphorus. Liza *et al.* (2001) maintained that low phosphate availability favored lateral root growth over primary root growth, through increased lateral root density and length, and reduced primary root growth mediated by reduced cell elongation. The reduction in root depth observed in IT93K-452-1 compared to the other varieties, regardless of seasonal changes, could be due to genetic variation compared to IT93K-452-1. Variety IT93K-452-1 exhibited stability in root length and may be a result of its genetic stability.

3.2.3. Root and Shoot Biomass

Phosphorus rates had significant effects on shoot and root biomass (Table 3). High shoot and root biomass were recorded in plots treated with 60 kg P_2O_5 /ha and 30 kg P_2O_5 /ha, while low shoot and root biomass were recorded in plots fertilized with 0 kg P_2O_5 /ha. The response to phosphorus application could be attributed to an increase in assimilate production and storage as a result of phosphorus (Kang and Naggos, 1983). Phosphorus supply increased the ability of the shoots and roots to store carbohydrates, hence increased the weight of shoots and roots (Kang and Naggos, 1983).

3.2.4. Number of Nodules and Nodule Dry Weight

Tillage methods and phosphorus rates had significant effects on number of nodules and nodule weight. The higher number of nodules as well as high nodule weight recorded in zero tillage among tillage methods could be attributed to the provision of an enabling environment for host x rhizobium interaction, thus forming more nodules. The high number of nodules in 30 kg P_2O_5/ha and 60 kg P_2O_5/ha could be because nodules are strong sinks for phosphorus, thereby increasing production and partitioning of assimilates in favor of nodulation. Results have demonstrated that legumes well supplied with phosphorus nodulated well (Seripong and Masayna, 1984).

3.2.5. Nitrogen Fixed and Percentage Nitrogen Derived From Atmosphere

N fixed was significantly affected by the sole effects of tillage and phosphorus levels, respectively (Table 4). More nitrogen was fixed in reduced tillage (0.39 g/plant) than in manual ridge tillage (0.30 g/plant) (Table 4). This can be due to lesser perturbation of the soil and the rhizobial population in the reduced tillage than in the manual ridging. The significantly high amount of nitrogen fixed at 60 kg P_20_5/ha plots in both planting periods (Table 4) can be attributed to the enhancement of nodule weight and shoot biomass as a result of phosphorus applied. Nkaa *et al.* (2014) confirmed that a higher rate of phosphorus application led to higher nitrogen fixation. Nitrogen fixed was significantly affected by the interaction between tillage methods and phosphorus rate (Table 6). The high amount of nitrogen fixed under zero tillage and when 60 Kg P_20_5 / ha of fertilizer was applied compared to the interaction of other tillage methods with 60 Kg P_20_5 / ha (Table 6) could be as a result of a favorable environment provided by zero tillage leading to increased rhizobial activity. Zhang *et al.* (2012) confirmed that in no-tilled plots, there are higher rhizobial populations than tilled plots. Ferrera *et al.* (2000) stated that rhizobial isolates from zero-tilled plots fixed higher atmospheric nitrogen than tilled plots. Van Kessel and Hartley (2000) stated that no tillage leads to stimulation of nitrogen fixation. These results may also explain why zero tillage plots recorded higher nodule dry weight. N fixed was significantly affected by the interaction between variety and phosphorus level (Table

4). N fixed was, however, significantly highest when 60 kg P_20_5 /ha was applied compared to the other P levels, regardless of cowpea variety (Table 7). In the early planting season, IT93K-452-1 fixed more N that was not significantly different from N Fixed by the other varieties receiving 60 kg P_20_5/ha (Table 7). In the late planting season, the reverse was however the case with IT90K-277-2 fixing more N when fertilized with 60 kg P_20_5/ha (Table 7). On the other hand, N fixed by IT99K-573-1-1 was significantly higher than that of other varieties when no P was added in the late planting season (Table 7). The difference in nitrogen fixed among cowpea varieties could be due to differences in their genetic makeup which could have differentiated these varieties in their interaction with different subsets of rhizobial population. Cowpea varieties vary in levels of promiscuity by the signals they send to potential rhizobial associates. This variance is contained in the flavonoids and isoflavonoids secreted by the root of cowpea in a bid to attract specific rhizobial populations prior to nodule initiation (Brencic and Winans, 2005). Nitrogen fixed was also significantly affected by the interaction between tillage method and variety (Table 4). In the early planting season, IT90K-277-2 fixed more N than the other varieties under zero tillage. Nitrogen fixed was, however, not statistically different from N fixed by the other varieties (Table 8). Similarly, in the late planting season, IT90K-277-2 fixed statistically higher N than the other varieties under zero tillage (Table 8). The other varieties (IT93K-452-1 and IT99K-573-1-1) recorded significantly higher N fixed only when they were cultivated under manually prepared ridges (Table 8). This implies that the amount of N fixed will vary with variety and also tillage method. IT93K-452-1 and IT99K-573-1-1 preferred manual tillage in the late season in order to increase N fixed while in the early season, they prefer zero tillage. Our results have shown that these varieties have lower root depths compared to IT90K-277-2 and should prefer manual tillage in order to explore soil nutrients and rhizobia population especially in the late and drier season when root penetration becomes more difficult.

3.2.6. Fodder yield

Tillage, phosphorus rates, and crop variety all had a significant effect on fodder yield (Table 5). Among the tillage methods, the highest fodder yield was recorded in zero tillage, while the least fodder yield was recorded in manual tillage (Table 6). The high fodder yield recorded in zero tillage among tillage methods in both planting periods can be due to the higher soil organic carbon content as a result of minimal disturbance of the soil. This could have played a role in the adsorption of nutrients, further explaining why fodder yield was highest in 60 kg P_20_5/ha and lowest in 0 kg P_20_5/ha during the early and late planting periods (Table 6). This agrees with the observations of Weber (1996) that legumes require a higher amount of phosphorus for optimal growth. In the early season, IT90K-277-2 produced the highest fodder yield, followed by IT93k-452-1 and IT99k-573-1 in that order. In the late season, IT93k-452-1 recorded the highest fodder yield, followed by IT99k-573-1-1 and IT90K-277-2 in that arrangement (Table 6). This signifies that seasons can alter the accumulation of dry matter along genetic pathways. This should not be taken for granted, especially now that climate change is raising concerns. The most genetically stable variety should be one that maintains stability in fodder and yield across varying environmental and climatic conditions. In the early planting season, regardless of variety, the application of 60 kg P_20_5 /ha recorded the highest fodder yield (Table 10). In the late planting season, the fodder yield of IT93k-452-1 was highest when 30 kg P_20_5 /ha was applied, while that of IT99k-573-1-1 was maximized when 0 kg P_20_5 /ha was added (Table 10). Conversely, the fodder yield of IT90K-277-2 was highest when 60 kg P_20_5 /ha was supplied (Table 10). This differentiation in response implies that the demand for phosphorus varies along genetic pathways and that IT90K-277-2 has the highest demand for phosphorus.

3.2.7. Grain yield

Tillage, phosphorus rates, and crop variety all had a significant effect on grain yield (Table 6). Among tillage methods, the highest grain yield was recorded in zero tillage, while the least grain yield was recorded in manual tillage (Table 6). The high grain yield recorded in zero tillage, among tillage methods in both planting periods (Table 6), can be attributed to the high nitrogen-fixing activities of the soil rhizobial population and increased organic carbon observed in zero tillage, which in turn could adsorb applied phosphorus, known to boost the yield of legumes. This further explains why grain yields were highest at 60 kg P/ha and lowest at 0 kg P/ha during the early and late planting periods (Table 6). In both seasons, IT99k-573-1-1 recorded the highest grain yield, followed by IT93k-452-1 and IT90K-277-2 in that arrangement. This is a reflection of genetic stability across the seasons and should not be ignored, considering the threats posed by negative climate change. Averagely, grain yields were lower in the early season than in the late season because cowpea, being a late-season crop, performed better during the late planting period. Studies have shown that growing cowpea in the rains (July to September) will increase fodder yield at the expense of grain yield. Ziska and Hall (1983) observed that lengthening the irrigation interval, which is synonymous with the dry season, resulted in less vine elongation and less shoot biomass production. Growing cowpea towards the drier period increases the accessibility of plant roots to nutrients due to the upward movement of nutrients, especially in sandy soils, and encourages the partitioning of assimilates in favor of seeds rather than shoots. The seed yield of cowpea was significantly affected by the interaction between variety and phosphorus level (Table 11). In the early and late seasons, the highest yield produced by IT90K-277-2 was recorded when 0 kg P/ha was applied (Table 11). In both seasons, IT93k-452-1 recorded its highest grain yield when 30 kg P_2O_5 / ha or 60 kg P_2O_5 / ha was supplied (Table 11), while IT99k-573-1-1 obtained its highest grain yield when fertilized with 60 kg P_2O_5 / ha (Table 11). This trend is in the opposite direction to that of fodder yield.

Yield increase in cowpea is most likely a response to high demand for nutrients like phosphorus, in addition to the efficient use of phosphorus and other nutrients. Seed yield of cowpea was significantly affected by the interaction between tillage and variety (Table 12). In the early and late seasons, and under zero tillage, IT99k-573-1-1 produced its highest grain yields of 404 kg/ha and 417 kg/ha, respectively, while IT90K-277-2 produced its highest grain yields of 126 kg/ha and 137 kg/ha, respectively (Table 12). On the other hand, in both seasons, IT93k-452-1 recorded its highest grain yields of 400 kg/ha and 422 kg/ha, respectively, under manual tillage (Table 12). Although zero tillage has been encouraged by most authors (Odofin et al.), yield response is also a function of crop variety. This result has demonstrated that while IT93k-452-1 would obtain its highest grain yield under manual tillage, IT99k-573-1-1 and IT90K-277-2 would obtain their maximum yield under zero tillage. This has so much to do with root length or depth such that IT99k-573-1-1 and IT90K-277-2, with longer root length, will require zero tillage, while IT93k-452-1, with shorter root length, will require manual tillage.

3.3. Conclusion

This study has evidently shown that zero and reduced tillage improved soil organic carbon, root biomass, shoot biomass, biological nitrogen fixation, fodder and grain yield, while manual tillage improved seedling emergence and root depth of crops.

Application of phosphorus fertilizer is vital in cowpea production as it improved nodulation, nitrogen fixation, root and shoot biomass, as well as fodder and grain yield. Application of higher rates of phosphorus resulted in higher nitrogen fixation, root and shoot biomass, as well as higher fodder and grain yield.

Cowpea variety also influenced fodder and grain yield. IT90K-277-2 performed best in fodder yield among the cowpea varieties irrespective of tillage methods and rates of phosphorus fertilizer applied, while IT99K-573-1-1 performed best in grain yield irrespective of tillage methods and rates of phosphorus fertilizer applied. The most genetically stable variety across the seasons was IT90K-277-2, since it maintained the same positions across seasons for most of the soil and crop observations taken. Yield was, however, more stable under the cultivation of IT99K-573-1-1 than IT90K-277-2.

3.4. Recommendations

Zero and reduced tillage should be encouraged, particularly when cowpea is cultivated on sandy loam soil in the southern Guinea savanna agro-ecological zone of Nigeria, as they improved soil organic carbon, nitrogen fixation, and cowpea performance. For best performance in cowpea production, and when climate change is minimal, farmers are encouraged to plant IT99k-573-1-1 on zero-tilled soil with phosphorus application at the rate of 60 kg ha^{-1}. IT90K-277-2, which is the most genetically stable variety across seasons, should, however, be considered for further investigations in the face of negative climate change.

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