Tillage Effects on Some Soil Physical Properties and Yield of Cowpea (Vigna unguiculata) in the Humid Rain Forest of Akure, Nigeria

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Moisture content;
Grain yield;
Biomass yield.

A B S T R A C T

Tillage operations have a major influence on the penetration resistance and physical characteristics of soils, roots growth, biomass and grain yield of tropical crops. Field experiment was conducted on sandy clay loam soil of Akure in the south west of Nigeria to determine the influence of different tillage systems on soil bulk density, penetration resistance, moisture content and growth characteristics of cowpea. There were three soil treatments plots A, B and C each with 5 x 11.2 m^2 dimension. The treatment applied on plot A was zero-tillage treatment (ZT) using paraquat herbicide, plot B had Minimum tillage (MT) using light implement (cutlass and hoe) while the plot C was under conventional tillage system (CT) using tractor mounted disc plough. The soil tillage treatments were replicated four times in a randomized complete block design totalling 12 plots. Zero-tillage progressively increased soil bulk density between 1.59 g cm^{-3} to 1.91 g cm^{-3} at the 0-30 cm soil depth. Highest moisture content of 15.98 % was obtained at the 0 – 10 cm soil layer in plots under zero tillage at the 5 weeks after planting (5WAP). During the 5th week after planting, soil penetration resistance ranged from 710 kPa under zero tillage to 680 kPa under minimum tillage and 340 kPa under disc ploughed plots (conventional tillage). Disc ploughed plots which produced the lowest soil penetration resistance gave the best cowpea (Vigna unguiculata) yield, an indication of the need for soil pulverization to enhance crop growth and yield. The results show that tillage treatments affect moisture retention, especially at 20 – 30 cm soil layers and thus the ease of cowpea roots penetration resulting in improved cowpea growth and yield parameters. The highest grain yield of cowpea with mean value of 0.64 (±0.03) t ha^{-1} was obtained in plots under convectional tillage treatment. The mean grain yield of 0.52 (±0.03) t ha^{-1} was recorded in plots under minimum tillage while zero tillage revealed a mean yield value of 0.41(±0.02) t ha^{-1}. Finding from the research showed that the yield and yield components of cowpea were raised in the plots under conventional tillage system compared with other tillage systems.

1. Introduction

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Tillage operations break up soil into smaller particles. Excessive tillage may pulverize soil aggregates, destroying the structure that provides desirable pore space. Many successful attempts have been made to utilize forms of reduced tillage; however, the constraints of soil type, large amounts of crop residue, and wet climate may often necessitate the continued use of full topsoil tillage (Carter, 1994a). According to Mosaddeghi *et al*., (2009), tillage is the mechanical manipulation of soil to control weeds, break crusts to help infiltration and seedling emergence, to dispose of pests or crop residues and to develop a desirable soil tilth for seedbeds and crop establishment. A number of different minimum tillage systems is adopted for soil and water conservation, to control weeds and ensure crop growth ahead of the germination of new flush of weeds in order to sustain agricultural productivity (Fasinmirin and Reichet, 2011). Tillage operations such as ploughing are known to influence root growth. Lal *et al.*, (1989) reported that elimination of tillage on poorly drained soils adversely affected root growth of crops. It is clear that in some soils, high mechanical impedance of the surface soil can influence the distribution of roots in the profile. It slows the downward progression of roots, and the root system is restricted to the upper parts of the profile. Penetrability is a system of measuring soil compaction, as defined by Bradford (1986), "Soil penetrability is a measure of the ease with which an object can be pushed or driven into the soil." Penetrability can help measure root growth inhibition caused by compaction. Penetration resistance measurements of soil can also be used to assess the need for tillage operations, which help to maintain effective plant rooting and facilitate good water and nutrient uptake (Veenstra *et al*., 2006). Bulk density measures the mass per unit volume of the soil. The higher the bulk density, the less

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porosity that is available for air, water, and biological activity. Soil compaction is a major concern for agricultural systems. Compaction is caused by cattle and equipment impacts such as tractor tires, harvesting and tillage equipment (Lal and Shukla, 2004).

The wheel traffic from farm implements or animal trampling can destroy pores causing higher penetration resistance and can cause higher soil bulk densities (Fuentes *et al*., 2004). Hydraulic conductivity, which reflects soil structural properties such as porosity, pore – size distribution and pore continuity, is used as an index for field drainage. When soil become compacted, changes in porosity and pore – size distribution caused the hydraulic conductivity to decrease, and penetration resistance and dry bulk density tend to increase (Lowery and Schuler, 1994) Compaction has an adverse effect on plant properties such as seedling emergence, root growth, and crop yield. Compaction also affects soil properties such as aggregate stability, erodibility and erosion, and water infiltration and drainage (Fuentes et al., 2004; Lal and Shukla, 2004). Particle size distribution, soil organic matter, moisture content, and bulk density affect soil strength and compaction. Soils containing more clay than sand tend to have more strength and cohesion (Lal and Shukla, 2004). The determination of the influence of different tillage systems on the strength and chemical characteristics of sandy clay loamy soil can be of importance in the yield rate. Over the years, practices used for the mechanical manipulation of soil have undergone significant operative and technological changes. Most recent tillage operations have allowed a substantial increase in soil productivity and decrease in energy consumption (Comegna *et al.*, 2000). Tillage practices generally lead to an overall improvement in the hydrological characteristics of soil, so as to create optimal crop vegetative conditions and reducing soil erosion problems (Douglas *et al.*, 1981; Hamblin and Tennant, 1981; Horton *et al.*, 1989; Datiri and Lowery, 1991; Wu *et al*., 1992).

One major consequence of tillage according to Comegna *et al*., (2000) is the partial changes to some soil physical and chemical properties, especially at the surface layer, such as total porosity, continuity and of the pore system, pore-size distribution, surface roughness, degree of compaction, and hence bulk density, as well as nutrient distribution. Adoption of the conservation tillage has revealed the beneficial long-term effects on soil physical, chemical, and biological properties (Cannel and Hawes, 1994; Tebrügge and Düring 1999; FAO, 2000; Holland, 2004). Many soil physical, biological and chemical properties are affected by different tillage systems and these affect crop growth. Several studies have evaluated the effect of tillage and soil amendments on root growth (Anderson, 1987). However, there is limited information on the combined effects of different tillage systems on the strength and physical characteristics of sandy clay loam soil under cowpea (Vigna unguiculata) cultivation in Akure.

Therefore, this research will provide useful information on the physical and penetration characteristics of arable soil of Akure, in the rainforest climate of Nigeria, which invariably will recommend sustainable soil management strategies for crop improvement and productivity in a growing economy of Nigeria. Cowpea (Vigna unguiculata L. Walp) is considered the most important food grain legume in the dry savannas of tropical Africa, where it is grown on more than 12.5 million hectares of land. It is rich in quality protein and has energy content almost equivalent to that of cereal grains; it is a good source of quality fodder for livestock and provides cash income. Cowpea also plays an important role in providing soil nitrogen to cereal crops (such as maize, millet, and sorghum) when grown in rotation, especially in areas where poor soil fertility is a problem Dugje *et al*., (2009). Priority must be given to small holder farmers because they constitute about 95% of farming household in Nigeria and produce most of the food crops consumed in the country (Adesina, 1991). Cowpea is a major food crop and is widely grown in Nigeria, however, with increasing population over the years, the demand for the crop had gone up but the production has not been increased significantly (Agwu, 2001). The research was aimed at determining the effects of bulk density and mechanical characteristics of soil on root penetration and yield of cowpea under different tillage practices in Akure, Nigeria.

2. Materials and methods

2.1 Site description

The research was conducted between August and November, 2013 at step B (science and Technology Education Post-Basic) site of the Federal University of Technology, Akure (FUTA), Akure, Ondo state, Nigeria. Akure is located on latitude 70 101 North and longitude 50 051 East. The soil of the study area is a sandy clay loam soil according to USDA textural classification of soil. Akure has a land area of about 2,303 sq km and is situated in the western upland area within the humid region of Nigeria at latitude 70 161 North; longitude 50 131 North. The area has a general elevation of between 300 -700 meters above mean sea level. Local peaks rise to 1000 meters; other hill-like structures which are less prominent rise only a few hundred meters above the general elevations (Fasinmirin and Konyeha, 2009). The pattern of rainfall is bimodal, the first peak occurring in June – July, and the second in September, with a little dry spell in August (Odekunle, 2004). The mean annual rainfall ranges between 1300 mm to 1500 mm. More than half of humid zone of Nigeria is covered by Pre-Cambrian basement complex, principally composed of metamorphic and igneous materials (Asiwaju Bello, 1999). The soils are light textured, fine sandy loam to fine sandy clay loam. The soil is moderately well supplied with organic matter and nutrients. Moisture holding capacity is moderately good. The soil of the environment is however subject to seasonal water logging for varying periods, but generally become dry during the dry seasons which falls within November and March (Adefolalu, 1983).

2.2 Field experimentation

Experiment was carried out to determine the influence of different tillage systems on the bulk density and penetration resistance of sandy clay loamy soil under cowpea (Vigna unguiculata) cultivation in Akure, Nigeria. The experiment was conducted from the period of peak rainfall (August) to onset of dry season (November) in 2013. There were three soil tillage treatments: No-tillage (NT), Minimum tillage (MT) and Convectional tillage

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- 30 cm.

The reduced bulk density under minimum and convectional tillage may have been caused by tillage operation, which reduced the soil aggregate sizes. Similar observation was reported by Sessiz *et al.* (2010) and Fasinmirin (2010) who reported that greater bulk densities in compacted soil is often lowered after tillage operation. Fasinmirin (2010) reported highest mean bulk density of (1.78 Mg m^{-3}) in soils under no-tillage and lowest mean bulk density of 1.56 Mg m^{-3} in soil under minimum tillage (MT). Grant and LaFond (1991) and Evett *et al.,* (1999) found higher bulk density under no tillage cultivation when compared to conventional tillage operations. The highest mean bulk density value of 1.91(±0.05) g cm^{-3} recorded in No-Till at 20 – 30 cm soil layer must have been caused by frequent soil settlements due to rainfall events with the consequent maintenance of stable soil structure and texture (Fasinmirin, 2010).

3.2 Moisture content

Tables 2 - 4 depict the mean percentage soil moisture content values obtained under the different tillage practices. All the treatments showed reduction in moisture content from the 3 weeks after planting (3WAP) to the 11 weeks after planting (11 WAP). Highest moisture content of 15.98 % was obtained between 0 – 10 cm soil layer in plots under No-Till during the 5 weeks after planting (5WAP). The highest soil water content recorded in the No-Till treatment plots must have been caused by high bulk density, which resulted to the compaction of soil superficial layer. This agrees with the findings of Ojeniyi and Adekayode (1999), and Olaoye (2002) who documented higher soil moisture content in No-Till treatment plots comparatively with disc ploughed plots. Minimum tillage had lower moisture content of 13.97 % between10 – 20 cm soil depth during the 5WAP, but at 20–30 cm soil depth, the moisture content rose to 14.21 %. Aikins and Afuakwa (2012) equally reported that disc ploughed soils had increased moisture contents. The results show that tillage treatments affect moisture content of the soil mostly between 20 – 30 cm soil layers. This in effect must have resulted to increased water uptake for improved yield of cowpea.

3.3 Soil penetration resistance

Tables 5 – 7 show the effect of the different tillage practices on soil penetration resistance. Tillage practice affects soil penetration resistance over the period of the experiment. Soil penetration resistance was highest in plots under No-Till when compared

Table 1 Mean bulk densities of sandy clay loam soil under different tillage systems

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 2: Moisture content (0-10) cm depth of sandy clay loam soil under different tillage Systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 3: Moisture content (10-20) cm depth of sandy clay loam soil under different tillage Systems

WAP	Moisture content (%) at (10 – 20) cm depth		
	Zero Tillage	Minimum Tillage	Convectional Tillage
3rd	21.08(±0.92)	23.25(±0.34)	21.35(±0.39)
4th	18.17(±0.46)	16.81(±0.23)	18.62(±0.23)
5th	13.47(±0.33)	13.97(±0.15)	13.82(±0.05)
6th	13.10(±0.15)	12.14(±0.11)	13.58(±0.12)
7th	12.65(±0.13)	14.51(±0.13)	14.90(±0.13)
8th	7.21(±0.06)	10.44(±0.09)	11.64(±0.16)
9th	8.27(±0.04)	10.27(±0.09)	10.16(±0.09)
10th	10.21(±0.08)	9.98(±0.08)	13.41(±0.23)
11th	7.87(±0.10)	9.17(±0.07)	11.67(±0.07)

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with penetration resistance in tilled soils. At 3 week after planting, the highest soil penetration resistance value of 480 kPa was recorded in the No-Till treatment plot.

The minimum tillage treatment plot had PR value of 320 kPa, while the lowest soil penetration resistance value of 270 kPa was recorded in plots under convectional tillage. During the 5 WAP, soil penetration resistance ranged from 710 kPa under No-Till to 680 kPa in minimum tillage and 340 kPa in convectional tillage treatment plots. Similar observation was made by Olaoye (2002) who reported higher soil penetration resistance in the soil under No-Till treatment plots comparatively with ploughed and harrowed Ferric Luvisol in the rain forest zone of Akure, Nigeria. The penetration resistance was 740 kPa under zero tillage, 540 kPa in minimum tillage and 420 kPa in convectional tillage treatment plots during the 9 WAP, which is in line with the study of (Aikins and Afuakwa, 2010) who reported that the No-Till plots which had the highest penetration resistance values were associated with the poorest cowpea performance since penetration resistance measures the energy that must be exerted by the young seedling to emerge from the soil. It indicates resistance that must be overcome by the young rootlets in their search for nutrients and water in the soil (Olaoye, 2002). Ploughed plots which produced the lowest soil penetration resistance gave the best cowpea (Vigna unguiculata) performance, which shows the need for tilling of the soil to the barest minimum.

The one-way ANOVA (3 WAP) of the mean penetration resistance of the different tillage systems at various depths (7.5 cm, 15 cm, 22.5 cm, 30 cm) showed statistically significant differences among the group means: 7.5 cm [$F(2, 9) = 288$, $p < .05$]; 15 cm [$F(2, 9) = 328.35$, $p < .05$]; 22.5 cm [$F(2, 9) = 1032$, $p < .05$] and 30 cm [$F(2, 9) = 228$, $p < .05$] indicating that not all three groups of the tillage systems resulted in the same penetration resistance value with depths. Specific analysis using Tukey pairwise comparisons was done between group means at different depth to determine which pairs of the three tillage systems means differed. At 7.5 cm depth, there was significant difference ($p<0.05$) between the corresponding means of zero tillage, minimum tillage and conventional tillage.

The mean penetration resistance of minimum tillage is significantly higher than that of zero tillage and conventional tiilage at PR 7.5. At 15 cm, 22.5 cm and 30cm depths, Tukey pairwise comparison also shows that mean penetration resistance of the three tillage systems are all significantly different. At 15 cm, mean penetration resistance of minimum tillage is significantly higher than that of zero and conventional tillage while mean value of plots under zero is significantly higher than that of conventional tillage. At 22.5cm and 30 cm depth, mean penetration resistance of zero tillage is significantly higher than minimum and conventional tillage. Also mean penetration resistance value of minimum tillage is higher significantly than that of conventional tillage which has the least mean value of penetration resistance among the three tillage systems. The one-way ANOVA (5 WAP) of the mean penetration resistance of the different tillage systems at various depths (7.5 cm, 15 cm, 22.5 cm, 30 cm) showed statistically significant differences among the group means: 7.5 cm [$F(2, 9) = 109.82$, $p < .05$]; 15 cm [$F(2, 9) = 254.05$, $p < .05$]; 22.5 cm [$F(2, 9) = 228.51$, $p < .05$] and 30 cm [$F(2, 9) = 710.65$, $p < .05$] indicating that not all three groups of the tillage systems resulted in homogenous penetration resistance value with depths. Tukey pairwise comparisons was done between group means at different depth to determine which pairs of the three tillage systems means differ. At 7.5 cm and 30 cm depth, there was significant difference ($p<0.05$) between the corresponding means of Zero tillage, Minimum tillage and Conventional tillage. The mean penetration resistance of zero tillage is significantly higher than that of minimum tillage and Conventional tiilage at PR 7.5 and PR 30. Likewise, mean penetration resistance value of minimum tillage is higher than that of conventional tillage. At 15 cm and 22.5 depths, mean penetration resistance of minimum tillage is significantly higher than that of Zero and Conventional tillage while mean value of Zero is significantly higher than that of Conventional tillage.

The one-way ANOVA (8 WAP) of the mean penetration resistance of the different tillage systems at various depths (7.5 cm, 15 cm, 22.5 cm, 30 cm) showed statistically significant differences among the group means: 7.5 cm [$F(2, 9) = 253.90$, $p < .05$]; 15 cm [$F(2, 9) = 624.72$, $p < .05$]; 22.5 cm [$F(2, 9) = 361.32$, $p < .05$] and 30 cm [$F(2, 9) = 96.01$, $p < .05$] indicating that not all three groups of the tillage systems resulted in the same penetration resistance value with depths. Tukey pairwise comparisons was done between group means at different depth to determine which pairs of the three tillage systems means differed. In all the depths, there was significant difference ($p<0.05$) between the corresponding means of zero tillage, Minimum tillage and Conventional tillage. The mean penetration resistance of zero tillage is significantly higher than that of minimum tillage and Conventional tillage at PR 7.5 PR 15, PR 22.5 and PR 30. At 7.5 cm, 22.5 cm and 30 cm, mean penetration resistance value of conventional tillage is higher than that of zero tillage. At 15 cm depths, mean penetration resistance of minimum tillage is significantly higher than that of zero tillage.

The one-way ANOVA (11 WAP) of the mean penetration resistance of the different tillage systems at various depths (7.5 cm, 15 cm, 22.5 cm, 30 cm) showed statistically significant differences among the group means: 7.5 cm [$F(2, 9) = 280.42$, $p < .05$]; 15 cm [$F(2, 9) = 175.72$, $p < .05$]; 22.5 cm [$F(2, 9) = 281.11$, $p < .05$] and 30 cm [$F(2, 9) = 180.92$, $p < .05$]. Post Hoc Comparison using Tukey HSD was done between group means at different depth to determine which pairs of the three tillage systems means differed. At 7.5 cm, 15cm and 22.5 cm depths, there was significant difference ($p<0.05$) between the corresponding means of Zero tillage, Minimum tillage and Conventional tillage. The mean penetration resistance of zero tillage is significantly higher than that of minimum tillage and Conventional tillage. Also mean penetration resistance value of minimum tillage is higher significantly than that of conventional tillage. Due to the hard core in the 30 cm depth in all the tillage systems at 11 WAP, pairwise comparison could not be done to determine which pairs of the tillage systems actually differed from one another.

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Table 4: Moisture content (20-30) cm depth of sandy clay loam soil under different tillage Systems

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 5: Multiple comparison of means of penetration resistance in different tillage treatment plots (3WAP)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 6: Multiple comparison of means of penetration resistance in different tillage treatment plots (5WAP)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ZT	MT	[illegible]	[illegible]
		CT	[illegible]	[illegible]
	MT	CT	[illegible]	[illegible]
PR 15	ZT	MT	[illegible]	[illegible]
		CT	[illegible]	[illegible]
	MT	CT	[illegible]	[illegible]
[illegible]	ZT	MT	[illegible]	[illegible]
		CT	[illegible]	[illegible]
	MT	CT	[illegible]	[illegible]
PR 30	ZT	MT	[illegible]	[illegible]
		CT	[illegible]	[illegible]
	MT	CT	[illegible]	[illegible]

[illegible]

Table 7: Multiple comparison of means of penetration resistance in different tillage treatment plots (8WAP)

Dependant	Treatment (i)	Treatment (j)	Mean Difference	Significance
PR 7.5	ZT	MT	219.75	0.001*
		CT	199.75	0.001*
	MT	CT	20.00	0.207ns
PR 15	ZT	MT	220.00	0.001*
		CT	220.25	0.001*
	MT	CT	0.25	0.999ns
PR 22.5	ZT	MT	240.00	0.001*
		CT	119.75	0.001*
	MT	CT	120.25	0.001*
PR 30	ZT	MT	139.75	0.001*
		CT	120.00	0.001*
	MT	CT	19.75	0.221ns

*-The mean difference is significant at the level of 0.05 level, ns – not significant, PR – penetration resistance, ZT-zero tillage, MT-minimum tillage, CT-convectional tillage.

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Table 14: Mean penetration resistance of sandy clay loam soil 8WAP under different tillage systems

Depth (cm)	Penetration resistance (KPa)		
	No-Till	Minimum Tillage	Conventional Tillage
0 - 7.5	[illegible]	[illegible]	[illegible]
7.5 - 15	[illegible]	[illegible]	[illegible]
15 - 22.5	[illegible]	[illegible]	[illegible]
22.5 - 30	[illegible]	[illegible]	[illegible]

Table 15: Mean penetration resistance of sandy clay loam soil 9WAP under different tillage systems

Depth (cm)	Penetration resistance (KPa)		
	No-Till	Minimum Tillage	Conventional Tillage
0 - 7.5	[illegible]	[illegible]	[illegible]
7.5 - 15	[illegible]	[illegible]	[illegible]
15 - 22.5	[illegible]	[illegible]	[illegible]
22.5 - 30	[illegible]	[illegible]	[illegible]

Table 16: Mean penetration resistance of sandy clay loam soil 10WAP under different tillage systems

Depth (cm)	Penetration resistance (KPa)		
	No-Till	Minimum Tillage	Conventional Tillage
0 - 7.5	[illegible]	[illegible]	[illegible]
7.5 - 15	[illegible]	[illegible]	[illegible]
15 - 22.5	[illegible]	[illegible]	[illegible]
22.5 - 30	***	[illegible]	[illegible]

Table 17: Mean penetration resistance of sandy clay loam soil 11WAP under different tillage systems

Depth (cm)	Penetration resistance (KPa)		
	No-Till	Minimum Tillage	Conventional Tillage
0 - 7.5	[illegible]	[illegible]	[illegible]
7.5 - 15	[illegible]	[illegible]	[illegible]
15 - 22.5	[illegible]	[illegible]	[illegible]
22.5 - 30	***	[illegible]	[illegible]

*** [illegible]

3.4 *Crop measurement*

During the 9th week after planting, convectional tillage treatment plots had the highest cumulative number of leaves (81±3.74) (Table 3.18), area of leaves (111.38 cm2), stem diameter (1.16 mm), height of plant (52.9 cm2), length of root (22.6cm) and root density RD1(22.0%), RD2 (33.0 %) and RD3 (44.0%) compared to the remaining zero and minimum treatment plots. It was observed in convectional tillage treatment plots that, the root density at the RD3 (third segment of root depth) to the root tip was 44.0 %, which strongly imply the root potential to grow and penetrate well into the soil and how effective the plant make use of soil water as a result of porosity obtained at tilled plots and nutrient supplies for growth and production as reported by (Adesigbin and Fasinmirin, 2011). In zero and minimum tillage treatment plots, the observations made were different (table 3.20 and 3.21).

However, Minimum tillage treatment plots had 73(±1.63) number of leaves , area of leaves (105.56 cm2), stem diameter (1.0 mm), height of plant (52.8 cm2), length of root (21.2cm) and root density RD1(27.2 %), RD2 (36.3 %) and RD3 (36.3%) , In the zero tillage treatment plot, the lowest value for the crop measurement was recorded, 61(±1.71) mean number of leaves was obtained at 9th week after planting, area of leaves (98.65 cm2), stem diameter (0.95 mm), height of plant (47.2 cm2), length of root (19.3cm) and root density RD1(21.0%), RD2 (47.3 %) and RD3 (31.5%).The root density in zero and minimum tillage treatment plots, were higher at upper layer of the plant root below the surface layer (RD1 and RD2 cm) and lower from the RD3 cm depth to the root tip. This was caused by soil compaction that resulted from zero tillage treatment plots, which led to the higher concentration of roots in the upper root layers and reduced roots in the deeper layers as reported by (Adesigbin and Fasinmirin, 2011). Observation made in convectional tillage treatment plots showed that RD3 (roots at the third segment depth) was able to penetrate well in loosen soil with the support of large pore space (porosity) available in the soil rather than stunted rooting penetration in zero tillage plot which was attributed to compaction.

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Table 8: Multiple comparison of means of penetration resistance in different tillage treatment plots (11WAP)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 9: Mean penetration resistance of sandy clay loam soil 3WAP under different tillage systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 10: Mean penetration resistance of sandy clay loam soil 4WAP under different tillage systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 11: Mean penetration resistance of sandy clay loam soil 5WAP under different tillage systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 12: Mean penetration resistance of sandy clay loam soil 6WAP under different tillage systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Table 13: Mean penetration resistance of sandy clay loam soil 7WAP under different tillage systems

[illegible]	[illegible]		
	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

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Table 18: Mean of crop measurement (number and area of leaves)

WAP	No-Till		Minimum Tillage		Conventional Tillage	
	NOL (no.)	AOL (cm²)	NOL (no.)	AOL (cm²)	NOL (no.)	AOL (cm²)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 19: Mean of crop measurement (stem diameter and height of plant)

WAP	No-Till		Minimum Tillage		Conventional Tillage	
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 20: Mean of crop measurement (length of root, LOR (cm))

WAP	No-Till	Minimum Tillage	Conventional Tillage
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Table 21: Percentage root density at the three segments of the entire root length

WAP	No-Till			Minimum Tillage			Conventional Tillage		
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

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3.5 Cowpea biomass yield

The cowpeas in all the treatment plots were harvested at the end of the experiment. Results show that convectional tillage treatment plots had the highest fresh/wet biomass (Table 22), dried biomass (Table 23), pod yield of cowpea (Table 24) and grain yield of cowpea (Table 25) compared with both zero and minimum tillage treatment plots. Cowpea dry matter yield was influenced by tillage practice. Similar observation was made by (Aikins and Afuakwa, 2010) who observed that the highest dry matter yield was recorded in the disc ploughing while the lowest dry matter yield was found in the no tillage plots. The highest grain yield of cowpea with mean value of 0.64(±0.03) tonne/hectare was obtained at convectional tillage, which is more than the average cowpea yield level of 538 kg/ha obtained in 1999 in Nigeria as reported by (FAOSTAT, 2000), while 0.52(±0.03) 0tonne/hectare was obtained in plots under minimum tillage and .41(±0.02) tonne/hectare at zero tillage. Also, highest mean value of pod yield of cowpea 0.75 (±0.04) was obtained at convectional tillage while 0.59 (±0.03) and0.50 (±0.03) was obtained at minimum and zero tillage respectively. The yield in convectional tillage must have been caused by most of the farm-level constraints that had been alleviated by the adoption of convectional tillage system. The result of root growth at different stages and grain yield of cowpea (Table 25) show that the adoption of convectional tillage system in cowpea production is favourable for plant growth, as aeration and microbial activities are not impeded. Hence convectional soil tillage is required to provide a favourable soil condition for cowpea growth. These results show the need and importance of tillage operation to increase agricultural productivity..

Table 22: Biomass yield (fresh/wet) of the cowpea at experimental plots

Biomass (fresh biomass) kg/ha			
Plot	Zero Tillage	Minimum Tillage	Conventional Tillage
Control	2646	3632	3538
Replicate 1	2596	3736	3770
Replicate 2	3006	3690	4526
Replicate 3	2746	2892	3304
Mean(STD)	2798(±166.56)	3050(±391.60)	3516(±226.32)

Table 23 Biomass yield (dried) of the cowpea at experimental plots

Biomass (dried biomass) kg/ha			
Plot	Zero Tillage	Minimum Tillage	Conventional Tillage
Control	816	1176	1320
Replicate 1	928	1192	1336
Replicate 2	968	1168	1496
Replicate 3	880	1144	1360
Mean	898(±65.44)	1170(±20)	1388(±78.75)

Table 24 Pod yield of cowpea at the different treatment plots

Pod yield of cowpea (tonne/hectare)			
Plot	Zero Tillage	Minimum Tillage	Conventional Tillage
Replicate 1	0.47	0.58	0.77
Replicate 2	0.48	0.61	0.70
Replicate 3	0.46	0.62	0.78
Mean(STD)	0.50(±0.03)	0.59(±0.03)	0.75(±0.04)

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Table 25 Grain yield of cowpea

[illegible]			
Plot	Zero Tillage	Minimum Tillage	Conventional Tillage
Replicate 1	0.41	0.51	0.65
Replicate 2	0.40	0.48	0.67
Replicate 3	0.42	0.53	0.63
Replicate 4	0.38	0.55	0.60
Mean (STD)	0.41(±0.02)	0.52(±0.03)	0.64(±0.03)

Considering all the treatment plots; plot A (zero tillage), plot B (minimum tillage) and plot C (convectional tillage), the latter gives ease of roots penetration which resulted to improvement in the yield of cowpea compared to the other treatments (zero and minimum tillage). The no tillage treatment presented the least growth and yield components parameters. The yield and growth characteristics of the cowpea grown under convectional tillage showed the disc ploughing is the best alternative for the production of cowpea (Vigna unguiculata) considering the soil and weather conditions of the experimental site. It can therefore be concluded from the result that convectional tillage operation should be incorporated in cowpea production to get better yield of cowpea in the humid tropical rain forest climate of Nigeria.

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