IMPACT OF TILLAGE PRACTICES ON PROPERTIES OF SOIL, EVAPOTRANSPIRATION AND PRODUCTIVITY OF COWPEA IN NIGERIA †

[IMPACTO DE LAS PRÁCTICAS DE LABRANZA EN LAS PROPIEDADES DEL SUELO, LA EVAPOTRANSPIRACIÓN Y LA PRODUCTIVIDAD DEL CAUPÍ EN NIGERIA]

Shittu Kabiru Alani [1*], Adeboye Omotayo Babawande [2], Oyedele Durodoluwa Joseph[3], Agunbiade Wasiu Lamidi[4], Babatunde Kayode Moses [5] and Murtadha Abdul-Salam Mosobalaje [1]

*[1]Department of Agronomy, College of Agriculture, Osun State University, P.M. B 4494, Osogbo, Osun State. Nigeria. Email: * kabiru.shittu@uniosun.edu.ng*
[2]Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, P.M.B. 13, Ile-Ife, Nigeria; Email: adeboyeob@oauife.edu.ng
[3]Department of Soil Science and Land Resources Management, Obafemi Awolowo University, P.M.B. 13, Ile-Ife, Nigeria. Email: d_oyedele@yahoo.com
[4] Department of Agricultural Engineering, Faculty of Engineering, P.M. B. 4494, Osogbo, Osun State Nigeria. Email: wasiu.agunbiade@uniosun.edu.ng
[5]Department of Soil Science and Agricultural Technology, The Oke-Ogun Polytechnic, Saki, Nigeria P.M.B.021, Saki. Email: mosobalaje.murtadha@uniosun.edu.ng
[*]Corresponding author

SUMMARY

Background: Tillage is one of the major threats to soil health which often results into soil physical degradation if not properly managed. Zero tillage is an alternative option from both economic and environmental protection of our soil resources points of view. **Objective.** To evaluate responses of cowpea (*Vigna unguiculata*) yield and evapotranspiration to different tillage practices. **Methodology**. The study was conducted in Obafemi Awolowo University, Ile-Ife Osun State, Nigeria using a replicated randomized complete block design with treatments consisting of Zero-tillage (ZT), Reduced tillage (RT), Conventional tillage + Mulch (CT + ML) and Conventional tillage (CT). **Results.** Soil penetration resistance (SPR) increased with the degree of soil manipulation during tillage practices. Penetration resistance (PR) across 15-30 cm in 2019 alone resulted in higher PR of 2.26 MPa for RT compared to 0.71, 0.72 and 0.79 MPa for ZT, CT + (ML and CT), respectively, approximately 218 %, 213 % and 186 % greater in RT than ZT, CT + ML and CT respectively. **Implications.** Cowpea production on sandy loam soil can be optimized with Zero tillage. **Conclusion.** Over a period of two years, ZT practice had the highest profit margin of $ 573, among the practices.

Keywords: tillage; yield; crop productivity; soil penetration resistance; evapotranspiration.

RESUMEN

Antecedentes: La labranza es una de las principales amenazas para la salud del suelo que a menudo resulta en su degradación física si no se maneja adecuadamente. La labranza cero es una opción alternativa desde el punto de vista de la protección tanto económica como ambiental del recurso suelo. **Objetivo**. Evaluar la respuesta de diferentes sistemas de labranza y evapotranspiración sobre la productividad del caupí (*Vigna unguiculata*). **Metodología.** El estudio se llevó a cabo en la Universidad Obafemi Awolowo, estado de Ile-Ife Osun, Nigeria, utilizando un diseño de bloques completos aleatorios replicados con tratamientos que consisten en labranza cero (ZT), labranza reducida (RT), labranza convencional + mantillo (CT + ML) y Labranza convencional (CT). **Resultados.** La resistencia a la penetración del suelo (SPR) aumentó con el grado de manipulación del suelo durante las prácticas de labranza. La resistencia a la penetración (PR) en 15-30 cm sólo en 2019 dió como resultado una PR más alta de 2.26 MPa para RT en comparación con 0.71, 0.72 y 0.79 MPa para ZT, CT + (ML y CT), respectivamente, aproximadamente 218 %, 213 % y 186 % mayor en RT que ZT, CT + ML y CT respectivamente. **Implicaciones**. La producción de caupí en

† *Submitted June 6, 2022 – Accepted December 19, 2022.* http://doi.org/10.56369/tsaes.4401

ISSN: 1870-0462.

suelo franco arenoso se puede optimizar con la práctica de labranza cero. **Conclusión**. Durante un período de dos años, la práctica de ZT registró el margen de beneficio más alto de $ 573, entre los tratamientos.
Palabras clave: labranza; rendimiento; productividad de cultivos; resistencia a la penetración del suelo; evapotranspiración.

INTRODUCTION

Tillage practices affect soil respiration, temperature, water content, pH, oxidation-reduction potential, and, soil microorganisms (Kladivko, 2001). In most farming communities, poor tillage directly affects soil aggregate, temperature, water infiltration and retention. These effects go beyond crop productivity and sustainability (Lori *et al*., 2017), emissions of greenhouse gas (Stavi and Lal, 2013), soil structure and carbon (C) sequestration (Guo and Gifford, 2002; Gattinger *et al.,* 2012). Intensive tillage over a long period of time causes soil degradation, compaction, and loss of soil and soil organic matter (SOM) in many agroecological areas around the world. Good soil management practices such as soil fertility preservation, managing water resources and irrigation systems, restoration of degraded land, implementation of integrated pest management, fertility utilization, and practicing conservation agriculture (Montagne *et al.*, 2007). By encouraging sustainable production of crops, good soil management practices specifically aim to improve the supply of healthy and high-quality food while also promoting market access and farmer livelihoods (Poole and Lynch, 2007).

Cowpea is a plant that provides nitrogen to the soil system through N_2 fixation hence enriches itself with protein with or without external application of mineral nitrogen fertilizers (Sprent, 2009). The crop plays a vital role in the livelihood of many people dwelling in the developing world (FAO, 2002), being a rich source of protein and carbohydrates with high nutritive values (Whitebread and Lawrence, 2006). Apart from being a component of the conventional cropping systems, it is well suited to dry and arid conditions owing to its adaptive capacity to various environmental stresses (Ddamulira *et al.,* 2015)

Soil physical quality is the capacity of a given soil to meet plant and environmental demands for water and aeration (McKenzie *et al*., 2011). Continuous land use and high economic growth threatens resources sustainability and agricultural land in Ile-Ife and other developing countries. The majority of agricultural lands are used for non-agricultural and recreational purposes, which has a negative impact on overall agricultural output.

There are three interdependent aspects of soil that affect crop productivity which are biological; chemical and physical health. Soil physical properties are less researched or studied compared to soil chemical and biological conditions. For instance, many commercial farmers use heavy farm machineries for land preparation without prior knowledge of the adverse effects of such practice on soil quality (Babalola, 2000). This practice consequently has led to the removal of the productive topsoil and exposes sub-soils to further degradation (Allen *et al.*, 2011). The suitability of soil for sustaining plant growth and biological activity is a function of its physical properties (Hillel, 2004). Various reports on soil degradation (Salako *et al*., 2006; Babalola *et al.*, 2007; Are *et al.*, 2011) indicated that plough and harrow are among the heaviest machines used for farming operations. Tillage has no significant impact on growth and yields of cowpea (Mupangwa *et al.*, 2012). Ile-Ife is an agrarian communities where tropical crops are being cultivated. In order to facilitate farming, many heavy agricultural equipment is used. However, the effect of these equipment on selected soil properties, soil strength and crop water use on cowpea, a key crop in the area have not been scientifically quantified. Information on response of cowpea to different tillage practices in African countries particularly Nigeria is limited. Therefore, the aim of the study was to determine the effects of tillage practices on soil strength, evapotranspiration and grain yields of cowpea in relation to economic value in Ile-Ife, Nigeria.

METHODOLOGY

Site Description

Field trials were conducted at the Teaching and Research Farm, Obafemi Awolowo University Ile-Ife, Nigeria (N 7º 31' E 4 º 33') Nigeria at 244 m above mean sea level (a.s.l.), in 2018 and 2019. The site is located in tropical rain forest and receives about 1,350 mm rainfall annually with a bimodal pattern that is typical of humid South of Nigeria (Akintola, 1986).

The first rainfall occurred between March and July while the second rainfall were between September and November. The average daily minimum temperature ranged between 20 ºC and 22 ºC and the average maximum temperature between 27ºC and 35ºC. Average humidity was 85 and 92% in 2018 and 2019 respectively. The experimental site was under fallow which was dominated by guinea grasses before the experiment established. The soil is deep, well drained and underlain by coarse grained granite gneisses bedrock. The soil is an Alfisol (Periaswamy and Ashaye, 1982) and locally classified as Iwo series

(Smyth and Montgomery, 1962.). The soil has brownish gray color with the surface texture varying from sandy loam to loamy sandy at sub-surface (Smyth and Montgomery, 1962)

Experimental Design and Layout

The experiments were conducted during the 2018-2019 for two consecutive rainy seasons on a gentle slope field (< 1 %). The treatments consisted of four tillage practices (Table 1) using sole cowpea (*Vigna unguiculata*) as the test crop. The treatments were arranged in a randomized complete block design in triplicate and consisted of zero tillage (ZT) and reduced tillage (RT) conventional tillage (CT) and CT + ML CT+ML, where mulch was applied three weeks after ploughing and harrowing.

The experimental plot measured 32 x 24 m and consisted of three blocks. Each block measured 28 x 4 m, and was divided into four plots. Plot measured 4 x 4 m each and adjacent plots were separated by an intervening space of 4 m, which allowed the tractor operations. Early maturing cowpea variety, (IT89KD-288) which takes 56-63 days obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, was planted on 21st September 2018 and 30th of August, 2019 at an approximate population of 133,333 per ha (0.5 m x 0.30 m, two seeds per hole). Weeds were controlled manually by using a local hand hoe. Cypermethrin, a pyrethroid compound was used to control insect fortnightly manually and was applied 2 weeks after planting to control insects.

Data collection started at two weeks after sowing and subsequent data collection was done on weekly basis until the crop started flowering to evaluate the effects of the treatments on selected soil physical health indicators and growth parameters. The surface and subsurface soil layer, i.e. (0–15 and 15-30 cm) of the soil profile, was sampled because this layer controls many critical and environmental processes, including seed germination and early seedling growth.

Soil Cone Index and Moisture Content

Soil penetration resistance (SPR) was measured using a stainless-steel cone-tipped penetrometer (Spectrum Technologies, Inc., IL, USA) with 20 mm diameter, 60° cone into the soil at a steady rate. Measurements were made in the row at three different places on each plot to the 50 cm depth at 10, 15, 30 and 50 cm apart.

Soil Sampling and Laboratory Analysis

Soil samples were collected with Edelman auger at 0−15 cm and 15−30 cm a week before the growing season in 2018. Composite soil samples at each depth were bulked, mixed thoroughly and sub-sampled for the determination of selected physical and chemical soil properties**.** The samples were air-dried at room temperature for some days and later crushed and sieved using 2 mm sieve before analysis. Soil pH was determined with a glass electrode pH meter in distilled

Table 1. Treatments and description.

Treatment	Description	Cost (USD ha^{-1})	
		2018	2019
Zero Tillage (ZT)	Plots were sprayed with mixed herbicides containing the active ingredient of dimethyl 2,4-D amine and Paraquat dichloride which each concentration was 825 g/L and 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water and 450 ml mixture of herbicide active ingredient herbicide Paraquat dichloride in the Knapsack sprayer.	111	113
Reduced Tillage (RT)	First plough (tillage depth of 12.5 cm) + spraying with herbicides containing the active ingredient dimethyl 2,4-D amine which concentration was 297 g/L. The dosage used was 30 ml of dimethyl amine herbicide active ingredient mixed with 14 liters of water in the Knapsack sprayer	155	157
Conventional Tillage + Mulching (CT + ML)	Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm) + mulch (7.5 t/ha Guinea grass (*Panicum maximum* grass residue)	222	224
Conventional tillage (CT)	Ploughed twice (tillage depth of 12.5 cm) + harrow (tillage depth of 12.5 cm)	213	216

1 USD = 365 NGN 2018, 1 USD = 360.0000 NGN 2019 (https://www.cbn.gov.ng/rates/exchratebycurrency)

water using 1:1, soil: water (Thomas, 1996). Total nitrogen was determined by the macro-Kjeldahl method (Bremner, 1996); available phosphorus was extracted with Bray-1 P solution by the molybdenum blue method on Technicon auto analyzer as modified by Olsen and Sommers (1982).

Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with neutral solution of 1.0 M NH_4OA_C. The K^+ and Na^+ concentrations in the extract were determined using the flame photometer while Mg^{2+} and Ca^{2+} were determined using the atomic absorption spectrophotometer (AAS). The exchangeable acidity (H^+) was extracted using 1.0 M KCl (Sims, 1996). Aliquot of the extract was titrated with 0.05 M NaOH to a permanent pink endpoint using phenolphthalein as indicator. The amount of NaOH used was taken to be equivalent to the total amount of exchangeable acidity in the aliquot taken (Odu *et al.*, 1986). Cation exchange capacity (CEC) was estimated by the summation of exchangeable bases (Hess, 1990).). Electrical conductivity (EC) was measured using a digital conductivity meter (VWR International, Bristol, CT). Particle size analysis was determined by hydrometer method (Okalebo *et al.*, 2002). Approximately 50 g of air soil was transferred to a dispersing cup, 20 ml of 5 % dispersion solution (sodium hexametaphosphate: Calgon) was added and the stirring cup was attached to a mixer and the sample was mixed for 60 seconds. Water was added to the suspension in the sedimentation cylinder to 1000 ml mark. The cylinder was shaken 50 times before standing. The hydrometer was carefully dropped into the suspension vertically at 1 minute after standing. The hydrometer level and temperature were measured using thermometer. The reading was repeated after 3 hours. The texture of the soil sample was determined using USDA textural triangle.

Evapotranspiration

Actual evapotranspiration (ET_a) was estimated using the soil water balance approach (Adeboye et al. 2017; Kisekka et al. 2019) in Eqn. (1):

$$ET_a = P - RO \pm \Delta S - D \quad (1)$$

where P *is* rainfall (mm); RO is surface runoff (mm); ΔS *is* change of soil water storage in the root zone from 0 to 60 cm; D is drainage (mm). Surface runoff within area of 1 m^2 in the replicates was channeled to a graduated plastics container and measured after each rainfall. Drainage was determined from the soil moisture content measured at regular intervals.

Water productivity

Seasonal water productivity was determined using the Eqn. (2):

$$WP = \frac{Y}{ET_a} \quad (2)$$

where Y is marketable yield (t ha^{-1}); ET_a is actual crop evapotranspiration (mm)

Agronomic parameters and yield of cowpea

Ten plants were randomly selected from each plot and number of leaves were counted starting from 14 days after planting (DAP) and subsequently at intervals of one week. The heights of the plants above soil surface were measured using a meter rule and average was determined. At physiological maturity, the cowpea pods within each plot were harvested and threshed manually and the seeds yield per plot were estimated. Grain yield was moisture corrected to 12.5 %.

Statistical Analysis

The data collected were subjected to analysis of variance (ANOVA) using SAS to assess treatments effects of tillage practices on selected agronomic parameters and soil physical properties. Differences between means were separated by using Duncan Multiple Range Test (p = 0.05) (SAS, 2011).

RESULTS AND DISCUSSION

Chemical and physical properties of the soil prior to cultivation

The soil pH (water) for 0-15 cm soil depth was 6.39 while that of 15-30 cm soil depth was 6.31 (Table 2). The soil was slightly acidic and can support the optimal growth of cowpea (SOSBAI, 2016). The electrical conductivity (EC) of the top and the sub-soil layers were less than 2 dS/m. This implies that the soil is not saline (Schoeneberger *et al.*, 2002). The cation exchange capacity (CEC) of the top and sub-soil was 2.69 meq. 100 g^{-1} and 2.20 meq. 100 g^{-1} respectively. Total N of top soil (0.25 %) and subsoil (0.28 %) were above the critical value of 0.11 % and was sufficient for crop growth (Horneck *et al.*, 2011).

The percent sand in 0-15 cm soil depth was 79.68 while the sand content in 15-30 cm soil depth is 81.68 %. Silt was 8.72 % at the top soil and 6.72 % at the sub soil (Table 2). The soil texture for both top and sub-soil was stated in Table 2.

Table 2. Physical and chemical properties of the soil at the experimental site.

Parameters	Depth (cm)	
	0-15	15-30
pH 1:1 (Soil: Water)	6.39	6.31
Exchangeable cations (cmol kg^{-1})		
Exchangeable Ca	0.95	0.93
Exchangeable Mg	0.34	0.30
Exchangeable Na	0.89	0.61
Exchangeable K	0.51	0.36
Hydrogen ion (H^+) (cmol kg^{-1})	0.32	0.46
Cation exchange capacity (CEC)	2.69	2.20
Effective cation exchange capacity ECEC (cmol kg^{-1})	3.01	2.66
Total Nitrogen (%)	0.25	0.28
Electrical conductivity (dS m^{-1})	0.41	0.46
Clay (%)	11.6	11.6
Silt (%)	8.72	6.72
Sand (%)	79.68	81.68
Textural class	Sandy loam	Loamy Sand

Soil penetration resistance (SPR)

The tillage practice had a significant impact on soil penetration resistance measurements to a depth of 50 cm for ZT, CT, CT + ML and RT under cowpea plant in 2018 and 2019 (Figures 1 and 2). All the treatments during the 2018 cropping season had decreased soil penetration resistance (SPR) at 10 and 30 cm soil depth. However, there was higher penetration resistance at 50 cm soil depth for all the treatments. The results of 2019 cropping season for SPR from 0 to 50 cm depth in CT, CT + ML, ZT and RT cropping season are presented in Figure 2. There was significantly high difference in SPR between RT and other treatments (CT, CT + ML, ZT) between 15 and 30 cm soil depth. SPR in RT treatment exceeded the critical level of 2 MPa (Hamza and Anderson, 2005) between this depth (15-30 cm) which would indicate potential soil compaction at this depth. Penetration resistance between 15–30 cm soil depth in RT plots reached 2.26 MPa and then decreased (Figure 2). This resistance (PR) across 15-30 cm in 2019 alone resulted in higher soil strength of 2.26 MPa for RT compared to 0.71, 0.72 and 0.79 MPa for ZT, CT + (ML and CT), respectively, which was 218 %, 213 % and 186 % greater in RT than ZT, CT + ML and CT respectively. The Lower SPR under CT and CT + ML were likely associated with deep plowing, thereby forming more soil macropores in CT and CT + ML than in RT. The soil PR in this study agreed with those reported in South Africa for pasture (Raper *et al.*, 2000), maize in Libya (Lampurlanes and Cantero-Martinez 2003), and India for wheat (Gathala *et al*., 2011) who stated that reduced tillage practices increased soil penetration resistance and bulk density when compared to other traditional tillage methods such as conventional and zero tillage practices.

Compared with other tillage practices, RT had a higher soil strength in the two seasons. As a result, mechanical resistance to root development and proliferation may exist in RT compared to other tillage practices (Shittu *et al.,* 2017). This could explain why there was a negative relationship between cowpea yield and soil penetration resistance. The lower SPR in the CT and CT + ML plots could be attributed to soil loosening to a depth of 30 cm due to tillage and crop residue assimilation in the top layer. Blanco-Canqui and Ruis (2018) and, Idowu *et al*., (2019) reported similar findings.

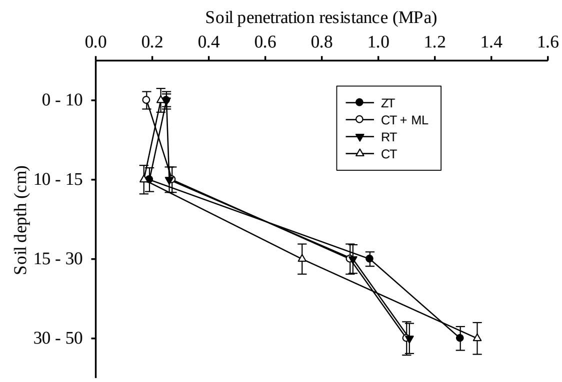

Figure 1. Mean soil penetration resistance during 2018 as a function of depth (0 - 50 cm) in different tillage methods the cropping season of cowpea.

Evapotranspiration

There were variations in the seasonal crop water use of the treatments. The total rainfall in the first season was 238 mm and 775 mm in the second season (Table 3). Zero tillage has the highest evapotranspiration and water productivity in the two seasons. The seasonal evapotranspiration for all the tillage practices were not significantly different in the two seasons despite their variations. In the first season, zero tillage had the highest water productivity while in the second season; minimum tillage had the peak water productivity and was significantly higher than the water productivities of other tillage practices. The water productivity under CT + ML and RT compares well with Moroke *et al.* (2011). However, the water productivity for other tillage practices were higher than those in Moroke *et al.,* 2011. The water productivity in the second season was higher and could be attributed to higher seasonal rainfall.

Effects of tillage practices on number of leaves, plant height

Tillage practices have an impact on the number of leaves and plant heights. Despite the fact that all of the treatments had nearly the same number of leaves at 2 WAP, an average of 6 leaves per plant, there were differences in number of leaves at 4 and 6 WAP in 2018 growing season (Figure 3). Zero tillage had 53 leaves per plant at 6WAP while the reduced tillage plot had 71 leaves per plant. A decline in the number of leaves in reduced tillage could be attributed to sudden increased SPR from 0.22 to 2.26 MPa within 15-30 cm soil depth (Figure 2). Majority of the active crop roots of most arable crops concentrate in this region in order to obtain nutrients (Thorup-Kristensen et al. 2020). Tillage greatly influenced yield and various growth parameters including root growth, leaf area index and dry matter accumulation (Gangwar *et al.*, 2004). Mechanical resistance greater than 2 MPa inhibits root proliferation in both monocot and dicot species. This is in line with previous studies (Pfeifer *et al.*, 2014; Colombi and Walter, 2016) which linked poor initial root development to the occurrence of high values of penetration resistance at 30 cm soil depth.

Grain yield

Higher yields were recorded for 2019 season with ZT recording 168 % > CT+ML (98 %) > CT (84 %); > RT (26 %) increases grain yield at the end of second cropping season (Figure 7). The highest (460 kg ha^{-1}) and the lowest (195 kg ha^{-1}) mean values of grain yield for the two seasons were obtained on CT and RT respectively (Figure 8). The high yield obtained from the CT system might be as a result of increase in number of leaves per stand and plant height in 2019 coupled with lower soil penetration resistance (Figures 3 and 4). RT had the lowest yield and might be because of reduction in both plant height and number of leaves at the end of 2019 cropping season, higher penetration resistance at critical rooting zone (15-30 cm) which may prevent the roots of the crops to nutrient availability and useful soil microorganisms may be responsible for this too (Mupangwa *et al.*, 2013).

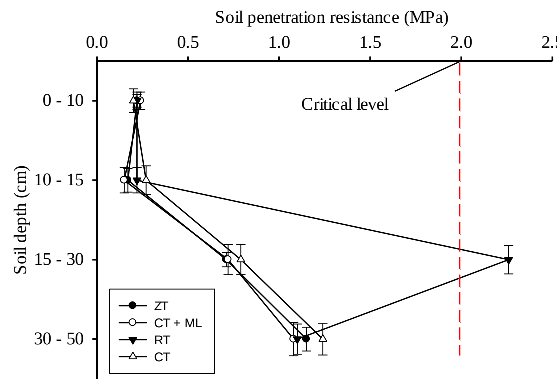

Figure 2. Mean soil penetration resistance during 2019 as a function of depth (0 - 50 cm) in different tillage methods the cropping season of cowpea.

Cost-benefit analysis

Treatment CT+ ML had the highest while ZT plots had the lowest input cost (Table 1). The differences were due to cost of hiring tractors and labor for mulching. Table 4 presents the income analysis for the 2018 and 2019 growing seasons for the various tillage treatments. The maximum income for the 2018 cropping season was obtained on CT and CT+ ML plots, respectively, at 333.72 and 300.35 USD. Similarly, the highest income of $614 and $595 for the 2019 season was obtained on CT and CT+ ML plots, respectively. Reduced tillage plots had the least income, $177 in 2018, and $223 in 2019.

Table 3. Water productivity for the two growing seasons.

Year	Treatment	Yield (kg ha^{-1})	Evapotranspiration (mm)	Water productivity (kg m^{-3})
2018	CT	210±14^{a}	166±9^{a}	0.79 ± 0.02^{b}
	ZT	172±18^{b}	181±18^{a}	1.05 ± 0.11^{a}
	CT+ML	166±13^{b}	176±16^{a}	0.60 ± 0.02^{b}
	RT	292±9^{a}	172±11^{a}	0.53 ± 0.05^{b}
2019	CT	596±10^{a}	651±5^{a}	1.09 ± 0.06^{b}
	ZT	563±16^{a}	663±23^{a}	1.18 ± 0.06^{b}
	CT+ML	578±18^{a}	649±12^{a}	1.12 ± 0.02^{b}
	RT	384±15^{b}	650±21^{a}	1.69 ± 0.08^{a}

Note**:** Means within a column (for each treatment factor) not sharing a lowercased italic letter differ significantly at the P < 0.05 level.

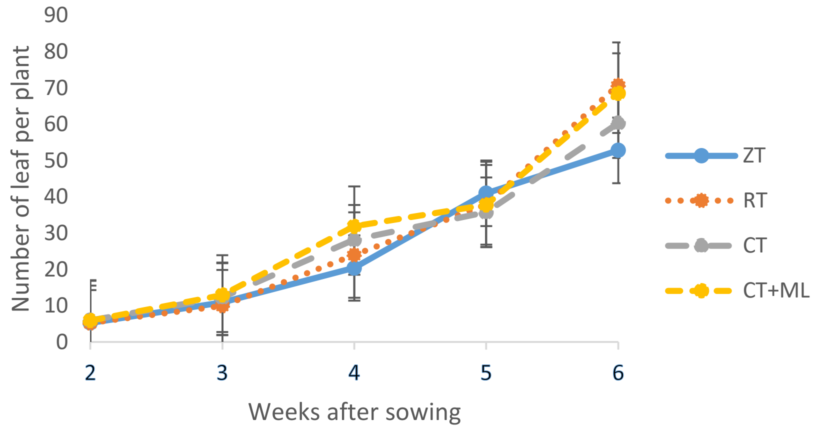

Figure 3. Effect of tillage on number of leaves of cowpea during 2018 cropping season.

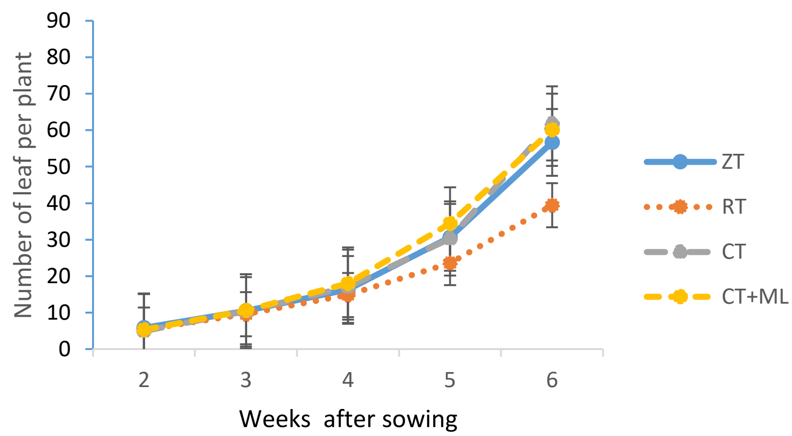

Figure 4. Effect of tillage on number of leaves of cowpea during 2019 cropping season.

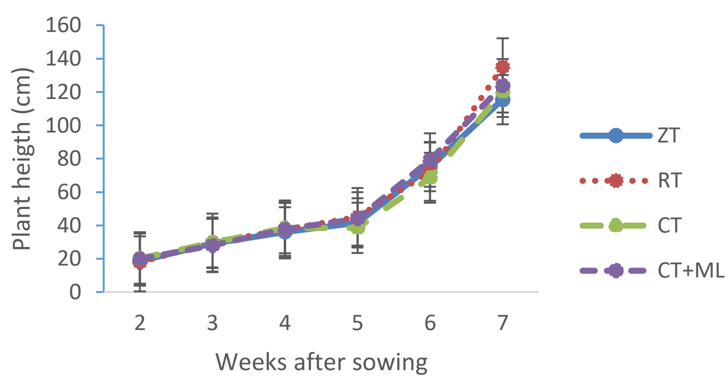

Figure 5. Effect of tillage on plant height of cowpea during 2018 cropping season.

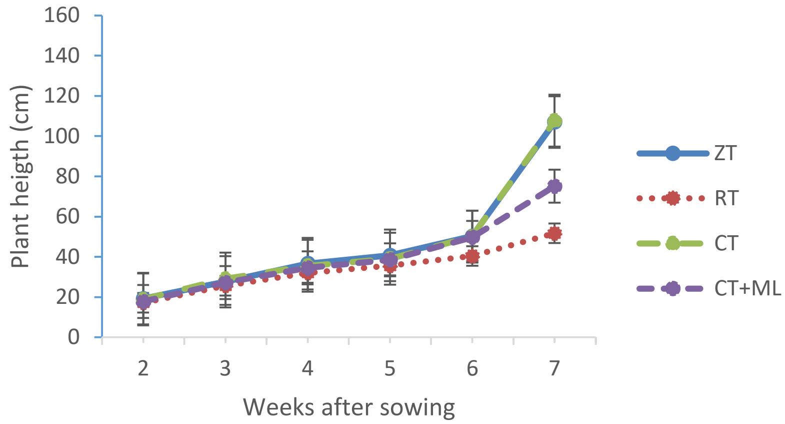

Figure 6. Effect of tillage on plant height of cowpea during 2019 cropping season.

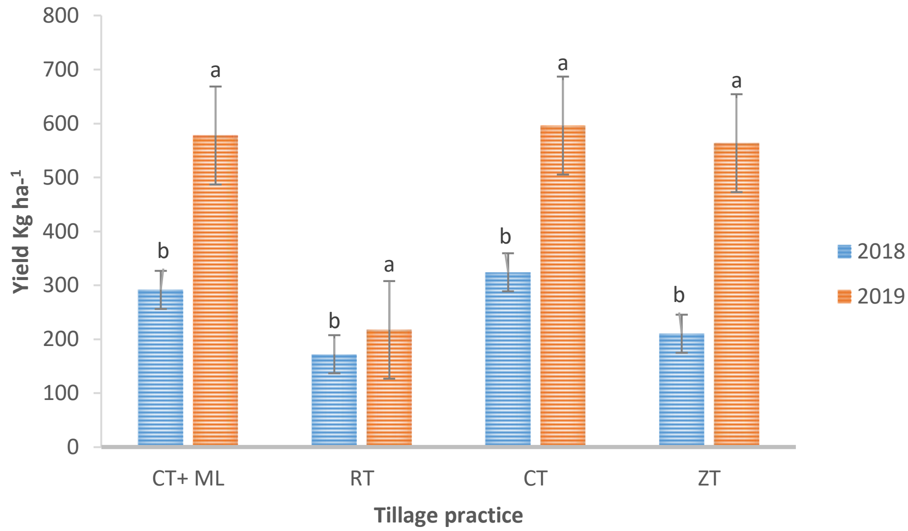

Figure 7. Mean values of grain yield of cowpea for 2018 and 2019 cropping season in response to different tillage practices

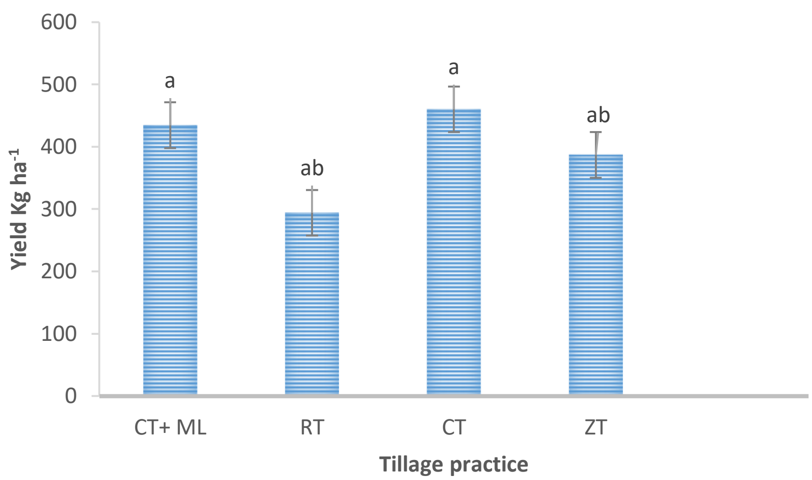

Figure 8. Mean grain yield of cowpea over the two cropping seasons in response to different tillage practices.

Table 4. Yield and income of the different tillage practices.

Treatments	2018		2019	
	Yield Kg ha^{-1}	Income ($ ha^{-1})	Yield Kg ha^{-1}	Income ($ ha^{-1})
CT	324	334	596	614
CT+ ML	292	300	578	595
ZT	210	217	563	580
RT	172	177	217	224

The highest profit earnings of 120 USD were obtained on CT plots for the 2018 while ZT ($468) had the highest earning in 2019 cropping seasons. The lowest profits of $ 22 and $66.98 for the 2018 and 2019 seasons, respectively, were obtained on RT plots. Considering the profit over two years and the relative energy requirements, ZT with $573, was found to be the most suitable tillage method for the optimum cultivation of cowpea on tropical sandy loam soils.

Table 5. Profit margins analysis of different tillage treatments.

Year	Treatment	Cost implication USD$ ha^{-1}	Income USD$ ha^{-1}	Profit USD$ ha^{-1}
2018	CT	213	335	122
	ZT	111	217	106
	CT+ML	222	300	78
	RT	155	177	22
2019	CT	216	614	398
	ZT	113	580	467
	CT+ML	224	595	371
	RT	157	224	67

CONCLUSION

Reduce tillage increased soil penetration resistance in the upper 30 cm horizon while Zero tillage had the highest profit margin. Cowpea consumed more water under Zero Tillage which resulted into higher water productivity. Zero tillage produced the highest seed yield. Zero tillage did not affect soil penetration resistance. Therefore, Zero Tillage could be adopted in sandy loam and loamy sand soils to prevent soil compaction in the upper 30 cm of the soil.

Acknowledgement
We acknowledge the technical staff members who assisted during field layout and collection of data

Funding. Not applicable

Conflict of interest. The authors declare no conflict of interest

Compliance with ethical standards. The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to

Data availability. Data are available with the corresponding author (kabiru.shittu@uniosun.edu.ng)

Author contribution statement (CRediT). K.A.Shittu, O.B.Adeboye, A.P. Adeboye Conception, design of the study, data collection and manuscript preparation**; D.J.Oyedele, J.A. Osunbitan** analysis of data**, K.M. Babatunde and M. A.Murtadha** literature support**.**

REFERENCES

Adeboye, O.B., Schultz, B., Adekalu, K.O. and Prasad, K., 2017. Soil water storage, yield, water productivity and transpiration efficiency of soybeans (*Glyxine max* L. *Merr*) as affected by soil surface management in Ile-Ife, Nigeria. *International Soil and Water Conservation Research,* 5(2), pp.141-150. https://doi.org/10.1016/j.iswcr.2017.04.006

Akintola, O., 1986. Rainfall distribution in *Nigeria*. Impact publishers, Ibadan, Nigeria. pp. 380.

Allen, B.L., Cochran, V.L., Caesar, T. and Tanaka, D.L., 2011. Long-term effects of topsoil removal on soil productivity factors, wheat yield and protein content. *Archives of Agronomy and Soil Science*, *57*(3), pp. 293-303. https://doi.org/10.1080/03650340903302294

Are, K.S., Babalola, O., Oke, A.O., Oluwatosin, G.A., Adelana, A.O., Ojo, A.O. and Adeyolanu, O.D., 2011. Conservation strategies for effective management of eroded landform: soil structural quality, nutrient enrichment ratios and runoff water quality. *Soil Science Society of Nigeria*, 176, pp. 252-263.

Babalola, O., 2000. Soil management and conservation in Nigeria. In: Akoroda, M.O.(Ed.), Agronomy in Nigeria. University of Ibadan, Nigeria, pp. 216–222.

Babalola, O., Oshunsanya, S.O. and Are, K., 2007. Effects of vetiver grass (*Vetiveria nigritana*) strips, vetiver grass mulch and an organomineral fertilizer on soil, water and nutrient losses and maize (*Zea mays* L.) yield. *Soil Tillage Research*, 96: pp. 6-18. https://doi.org/10.1016/j.still.2007.02.008

Blanco-Canqui, H. and Ruis, S.J., 2018. No-tillage and soil physical environment. *Geoderma*, 326, pp. 164-200. https://doi.org/10.1016/j.geoderma.2018.03.011

Bremner, J. M., 1996. Nitrogen-Total. In D. Sparks, A. Page, P. Helmke, R. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston, and M. E. Sumner (Eds.), *Methods of Soil Analysis,* pp. 1085-1121. *American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America* https://doi.org/10.2136/sssabookser5.3.c37

Colombi, T. and Walter, A. 2016. Root responses of triticale and soybean to soil compaction in the field are reproducible under controlled conditions. *Functional Plant Biology*, 43(2), 114–128. https://doi.org/10.1071/FP15194

Ddamulira, G., Fernandes Santos, C., Obuo, P., Alanyo, M. and Lwanga, C., 2015. Grain Yield and Protein Content of Brazilian Cowpea Genotypes under Diverse Ugandan Environments. *American Journal of Plant Sciences*, 6, pp. 2074-2084. https://doi.org/10.4236/ajps.2015.6132088

Food and Agriculture Organization of the United Nations (FAO), 2002. World Agriculture: towards 2015/2030. Summary Report, Rome, Italy, https://www.fao.org/publications. Downloaded on 19th August, 2022.

Gangwar, K. S., Singh, K. K. and Sharma, S. K., 2004. Effect of tillage on growth, yield and nutrient uptake in wheat after rice in the Indo-Gangetic Plains of India. *Journal of Agricultural Science*, 142, pp. 453–459. https://doi.org/10.1017/S0021859604004459

Gathala, M.K., J.K. Ladha, Y.S. Saharawat, V. Kumar, V. Kumar, and P.K. Sharma. 2011. Effect of tillage and crop establishment methods on physical properties of a medium-textured soil under a seven-year Rice-wheat rotation. *Soil Science Society America Journal* 75: pp. 1851– 1862. https://doi.org/10.2136/sssaj2010.0362

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., Mäder, P., Stolze, M., Smith, P., Scialabba, N. and Niggli, U., 2012. Enhanced top soil carbon stocks under organic farming. *Proceedings of the National Academy of Sciences of the United States of America*, 109(44), pp. 18226–18231. https://doi.org/10.1073/pnas.1209429109

Guo, L. B. and Gifford, R. M., 2002. Soil carbon stocks and land use change: a meta-analysis. *Global Change Biology*, 8(4), pp. 345-360. https://doi.org/10.1046/j.1354-1013.2002.00486.x

Hamza, M.A. and Anderson, W.K. 2005. Soil compaction in cropping systems: A review of the nature, causes and possible solutions. *Soil and Tillage Research*, 82(2), pp. 121-145. https://doi.org/10.1016/j.still.200 4.08.009

Hess, T.M., 1990. Tropical Soil Biology and Fertility: A Handbook of Methods. Edited by J. M. Anderson and J. S. I. Ingram. Wallingford: CAB International (1989), pp 171

Hillel, D., 2004. Introduction to Environmental Soil Physics. Elsevier Academic Press, Amsterdam, Netherlands.

Horneck, D.A., Sullivan, J.S., Owen, J.S. and Hart, J.M., 2011. Soil test interpretation guide. In: Oregon State University Extension Services Report. Oregon State University, Oregon. https://catalog.extension.oregonstate.edu/ec1478. Downloaded on 19th August, 2022.

Idowu, O. J., Sultana, S., Darapuneni, M., Beck, L. and Steiner, R. 2019. Short-term Conservation Tillage Effects on Corn Silage Yield and Soil Quality in an Irrigated, Arid Agroecosystem. *Agronomy*, *9*(8), pp. 455. https://doi.org/10.3390/agronomy9080455

Kisekka, I., Kandelous, M. M., Sanden, B. and Hopmans, J.W., 2019. Uncertainties in leaching assessment in micro-irrigated fields using water balance approach. *Agricultural Water Management*, *213*, pp. 107-115. https://doi.org/10.1016/j.agwat.2018.10.012.

Kladivko, E.J., 2001. Tillage systems and soil ecology. *Soil and Tillage Research*, *61*(1), 61-76. https://doi.org/10.1016/S0167-1987(01)00179-9

Lampurlanes, J. and Cantero-Martinez, C., 2003. Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barley root growth. *Agronomy Journal*, 95:526–536. https://doi.org/10.2134/agronj2003.5260

Lori, M., Symnaczik, S., Mäder, P., De Deyn, G. and Gattinger, A., 2017. Organic farming enhances soil microbial abundance and activity-A meta-analysis and meta-regression. *PLoS One*, *12*(7), pp. 1-25. https://doi.org/10.1371/journal.pone.0180442

McKenzie, B.M., Tisdall, J.M. and Vance, WH., 2011. Soil physical quality. In: Gliński, J., Horabik, J., Lipiec, J. (Eds.), Encyclopedia of Agrophysics. Springer Science +Business Media B.V., pp. 770–777.

Montagne, D., Cornu, S., Bourennane, H., Baine, D., Ratie, C. and King, D., 2007. Effect of Agricultural Practices on Trace-Element Distribution in Soil. *Communications in Soil Science and Plant Analysis*, 38(3-4), pp. 473-491. https://doi.org/10.1080/00103620601174411

Moroke, T. S., Schwartz, R. C., Brown, K. W. and Juo, A. S. R., 2011. Water use efficiency of dryland cowpea, sorghum and sunflower under reduced tillage. *Soil and Tillage Research*, 112(1), pp. 76-84. https://doi.org/10.1016/j.still.2010.11.008

Mupangwa, W., Twomlow, S. and Walker, S., 2012. Reduced tillage, mulching and rotational effects on maize (*Zea mays* L.), cowpea (*Vigna unguiculata* (Walp) L.) and sorghum (*Sorghum bicolor* L. (Moench)) yields under semi-arid conditions. *Field Crops Research*, *132*, 139-148. https://doi.org/10.1016/j.fcr.2012.02.020

Mupangwa, W., Twomlow, S. and Walker, S., 2013. Cumulative effects of reduced tillage and mulching on soil properties under semi-arid conditions. *Journal of Arid Environments*, 91, pp. 45-52. https://doi.org/10.1016/j.jaridenv.2012.11.007

Odu, C.T.I., Babalola, O., Udo E.J., Ogunkunle, A.O., Bakare, T.A., Adeoye, G.O., 1986. Laboratory manual for agronomic studies in soil, plant and microbiology.1st ed. Department of Agronomy, University of Ibadan, Ibadan, Nigeria. pp. 83.

Okalebo, J. R., Gathua, K. W. and Woomer, P. L., 1993. *Laboratory Methods of Soil and Plant Analysis: A Working Manual*. Tropical Soil Biology and Fertility Programme, pp. 88.

Olsen, S.R. and Sommers, L.E., 1982. Phosphorus. In: Page, A.L., (Ed.), Methods of Soil Analysis Part 2 Chemical and Microbiological Properties, American Society of Agronomy, Soil Science Society of America, Madison, pp. 403-430.

Periaswamy, S.P. and Ashaye, T.I., 1962. Updated classification of some southwestern Nigeria soils. *Ife Journal of Agriculture*, 4, pp. 25-41.

Pfeifer, J., Faget, M., Walter, A., Blossfeld, S., Fiorani, F., Schurr, U. and Nagel, K. A., 2014. Spring barley shows dynamic compensatory root and shoot growth responses when exposed to localised soil compaction and fertilisation. *Functional plant biology*, *41*(6), pp. 581–597. https://doi.org/10.1071/FP13224

Poole, N.D. and Lynch, K., 2007. Agricultural market knowledge: Systems for delivery of a private and public good. *Journal of Agricultural Education and Extension*, 9(3), pp. 117-126. https://doi.org/10.1080/13892240385300181

Raper, R.L., Reeves, D.W., Burmester, C.H. and Schwab, E.B., 2000. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. *Applied Engineering in Agriculture*, 16: pp.379–385. https://handle.nal.usda.gov/10113/14353

Salako, F. K., Kirchhof, G. and Tian, G., 2006. Management of a previously eroded tropical Alfisol with herbaceous legumes: Soil loss and physical properties under mound tillage. *Soil and Tillage Research*, *89*(2), pp. 185-195. https://doi.org/10.1016/j.still.2005.07.010

SAS Institute Inc., 2011. The SAS System for Windows, Release 9.2. Statistical Analysis Systems Institute, Cary, NC, USA.

Schoeneberger, P.J., Wysocki, D.A., Benham, E.C., Broderson, B., 2002. Field book for describing and sampling soils. Natural Resources Conservation, USDA, National Soil Survey Center, Lincoln, NE.

Sims, J. T., 1996. Lime Requirement. In D. Sparks, A. Page, P. Helmke, R. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston and M. E. Sumner (Eds.), *Methods of Soil Analysis*, pp. 491-515, American Society of Agronomy, Crop Science Society of

America, and Soil Science Society of America

Shittu, K.A., Oyedele, D.J. and Babatunde, K.M. 2017. The effects of moisture content at tillage on soil strength in maize production. *Egyptian Journal of Basic and Applied Sciences*, *4*(2), 139-142. https://doi.org/10.1016/j.ejbas.2017.04.001

SOSBAI, 2016. Irrigated Rice South-Brazilian Society. Arroz irrigado: recomendações técnicas da pesquisa para o Sul do Brasil (Irrigated rice: Technical research recommendations for Southern Brazil), Pelotas, pp. 200.

Sprent, J.I., 2009. Legume Nodulation: A global perspective. Wiley-Blackwell, John Wiley and Sons' Ltd, pp. 200.

Smyth, A.J. and Montgomery, R.F., 1962. Soil and Land Use in Central Western Nigeria, Government printers, Ibadan, Nigeria, pp. 10 – 84.

Stavi, I. and Lal, R., 2013. Agriculture and greenhouse gases, a common tragedy. A review. *Agronomy for Sustainable Development*, 33(2), pp. 275-289. https://doi.org/10.1007/s13593-012-0110-0.

Thomas, G.W. 1996. Soil pH and Soil Acidity. In D.L. Sparks, A. L. Page, P.A. Helmke, R.H. Loeppert, P.N. Soltanpour, M.A. Tabatabai, C.T. Johnston, and M.E., Sumner (Eds.), *Methods of Soil Analysis*, pp. 475-490, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Thorup-Kristensen, K., Halberg, N., Nicolaisen, M., Olesen, J. E., Crews, T. E., Hinsinger, P., Kirkegaard, J., Pierret, A. and Dresbøll, D. B., 2020. Digging Deeper for Agricultural Resources, the Value of Deep Rooting. *Trends in Plant Science*, *25*(4), pp. 406-417. https://doi.org/10.1016/j.tplants.2019.12.007

Whitbread, A. and Lawrence, J., 2006. Cowpea fact sheet for Grain and Graze. Available online: Whitebread available on http://lwa.gov.au/files/products/grain-andgraze pn20434/pn20434.pdf