Original scientific paper
Оригинални научни рад
UDC 631.415.2:635.654(669)
DOI 10.7251/AGREN2503185S

University of Banjaluka, Faculty of Agriculture
Agro-knowledge Journal

The impact of soil amendments on the moisture content, soil strength, and yield of okra on a loamy sand soil in southwest Nigeria

Shittu K. A.[1], Adeboye O. B.[2], Oladiran F. V.[1]

[1] *Osun State University, College of Agriculture, Faculty of Agricultural Production and Management, Osogbo, Osun State, Nigeria*
[2] *Obafemi Awolowo University, Faculty of Technology, Ile-Ife, Nigeria*

Abstract

The consequences of improper tillage and soil management are reflected through the decrease in soil health and reduction in crop yield. The objective of this study was to provide information about appropriate tillage practices and soil amendments that can not only improve the soil quality but also lead to optimal okra production in a sustainable way. A two-year study was conducted in the wet season of 2021 and 2022 at the Teaching and Research Farm, Ejigbo Campus, Ejigbo, Osun State, Nigeria. Three options for land preparation were involved, including the following treatments: i. slashing with the aid of cutlass, ii. spraying manually with glyphosate, and iii. conventional tillage. Three different types of nutrient management packages were applied. The moisture content in the soil was determined gravimetrically and soil penetration was measured by pushing a stainless-steel cone-tipped penetrometer (12.8-mm diameter, 30◦ cone) into the soil at a steady rate. The soil strength means of 1.65 and 1.98 MPa were recorded for an amended plot (AM) and non-amended (NA) treatment plots respectively, resulting in 16.7% decrease in soil strength when compared with NA experimental plots. Also, the mean soil strength in the first cropping season for the twelve treatments in 2021 (1.59 MPa) was significantly greater than that in the second cropping season of 2022 (1.30 MPa). This resulted in 18.2% reduction in average soil strength in the second cropping season between 0 to 30 cm soil depths. TRP (1.45 tons/ha) on one of the AM plots had the highest yield and was significantly greater than SPO (0.15 tons/ha) and SLO (0.13 tons/ha) on the NA plots by 867 and 1015% respectively at the 0.05 probability level. In comparison to a non-amended soil environment, soil amendment frequently results in healthier physical properties of soil that support a more favourable soil environment for plant growth.

***Key words**:* Relative humidity, Conventional tillage, Soil strength, Spraying, Tillage practices.

Introduction

Soil tillage is an essential agronomic technique that necessitates significant financial outlays and substantial energy inputs. According to Syromyatnikov et al. (2023), it is carried out to provide soil conditions that are favourable for plant growth and development. Additionally, according to Angon et al. (2023), tillage is one of the most important agricultural management practices that can alter the physical, chemical, and biological properties of soil and affect crop quality and yield. To maintain the soil quality needed for crops to grow well, it is crucial to choose the right tillage type and good soil amendment (Shahane & Shivay, 2021).

According to Thomas et al. (2020), tillage practices alter the bulk density, aggregate stability, soil water storage, and resistance to soil penetration. Because of more organic matter in the soil, reduced tillage and no-tillage systems typically improve water storage, aggregate stability, and infiltration rate (Farahani et al., 2022). In tillage investigations, bulk density and penetration resistance (PR) are the most often used indicators to assess soil strength. Penetration resistance (PR) is commonly employed as an index to quantify soil compaction, which is dependent on the tillage technique, depth of soil disturbance, and implement used (Hamza & Anderson, 2005). Therefore, variations in crop growth, development, yield, and quality can be easily explained by evaluating the impact of tillage depth on soil compaction. All tillage techniques generally decreased the resistance of the soil to penetration at the depth of tillage (Šarauskis et al., 2024). Using big combine harvesters and transport vehicles on highly moist soils results in strong compaction. The effects of soil compaction can continue for a long time or even be permanent, especially in soils that contain little clay (Shaheb et al., 2021). These alterations strongly affect root growth and functions and thereby contribute to crop production and leaching of agrochemicals. A common response of the root system to increasing soil strength is to decrease its length, concentrating roots in the top layer and decreasing rooting depth (Zhang et al., 2024). The depth and the tillage technique affect the bulk density, PR, and water movement in the soil—all indicators of soil porosity and compactness (Hamza & Anderson, 2005). Presently, there is a wide gap between food production and population growth in Nigeria and most of the developing countries. Some of the reasons for this gap emanate from poor yields that result from the inexperience in appropriate combination of soil tillage and proper soil amendment. For Nigeria to be self-sufficient in food production, efforts should be geared towards closing this gap. Some of such efforts should include investigating various tillage operations along with good soil amendments. In order to improve agricultural production, proper soil amendment coupled with appropriate tillage operations are key factors to put into consideration. However, information about the effect of these activities on selected physical properties (moisture content, soil strength) and okra yield in southwest Nigeria have not been properly quantified. A successful study on this matter can lead to improvement in sustainable production of food and soil health in the long run.

The aim of this present study is to evaluate the impact of soil amendment and selected tillage practices on the moisture content, soil strength, and yield of okra on a loamy sand soil in southwest Nigeria.

Material and Methods

Site and soil description

A two-year study was carried out at the Teaching and Research Farm, Ejigbo Campus, Ejigbo, Osun State, Nigeria, during the wet season of 2021 and 2022. The Ejigbo Teaching and Research Farm is situated in the Derived Savanna zone of southwest Nigeria at 7o52' ̓19"N, 004° 18' 28" E. The town of Ejigbo is located in Osun State, which is in southwest Nigeria's Derived Savannah agro-ecological zone. Prior to the experiment commencement in 2021, ten randomly selected locations on the site were used to gather soil samples. Prior to soil analysis, the soil samples were combined, allowed to air dry, and then sieved through a 2-mm screen. Granites, gneisses, and schists—the predominant parent material in Nigeria—are the crystalline basement complex rocks from which the soils at Ejigbo are formed (Bennet, 1980). The two rainy seasons last from mid-August to November and March to July. With dry and wet seasons, the climate is hot and muggy. The annual rainfall is approximately 950 mm, and the average humidity is 70.30%. The highest temperature is 32.80 °C, while the lowest temperature is 20.83 °C. At the experiment site, the siam weed (*Chromolaena odorata* L. King and Robinson), hemorrhage plant (*Aspilia africana Pers.* Adam), and broom weed (*Sida acuta* Burm) were the most common weeds.

Land preparation and experimental lay-out

Three tillage practices were used and these included slashing, spraying manually with glyphosate, and conventional tillage. Seven days after the initial plough on the designated experimental plots, second ploughing was conducted. The maximum depth of tillage was kept at 20 cm, and three different types of nutrient management packages were applied: the cow dung and poultry manure at the same rates (25 t ha^{-1} yr^{-1}, dry weight) (Ismail et al., 2010), 120 kg ha^{-1} N.P.K. (15:15:15) from chemical fertilizer, and three control plots (tillage without nutrient packages, i.e., SPO, SLO, and TRO). Composite soil samples at each depth (0-15 and 15-30 cm) were randomly taken, bulked, mixed thoroughly, and sub-sampled in order to determine selected physical and chemical soil properties. Table 1 presents the physiochemical characteristics of the soil used in the study. The same location was used for the 2021 and 2022 cropping of okra.

Tab. 1 - Physiochemical properties of the soil used for the analysis (2021-2022)

Soil Parameter	Soil Depth	
	0-15 cm	15-30 cm
Clay (%)	16	72
Silt (%)	10	10
Sand (%)	74	18
Texture (texture class according to USDA)	Sandy loam	Clay
Organic matter (%)	3.10	3.00
Total N (%	0.32	0.28
pH (H_2O)	5.40	5.29
Available P (mg kg^{-1})	10.68	10.24

Tab. 2 - Chemical composition (standard error in parentheses) of compost and manure used in the experiments (2021-2022)

Soil Parameter	Cow Manure	Poultry Manure
Organic matter (g kg^{-1})	295	423
Total N (%)	0.97	0.17
Total P (g kg^{-1})	2.60	4.00
Total K (g kg^{-1})	4.50	10.40
pH (H2O, 1:5)	7.20	7.51
Electrical conductivity (H_2O, 1:5) (d*S* m^{-1})	4.10	3.70

Cattle manure from a local smallholder farmer and poultry manure from the broiler house at the Osun State University in Ejigbo were the sources of the organic manure. The manure (cattle and poultry dung) was carefully mixed and larger particles were reduced by hand. For the studies conducted in 2021–2022, the Institute of Agricultural Research & Training in Ibadan, Nigeria, conducted an analysis of the poultry manure and cow dung's chemical makeup, as shown in Table 2. The manure was distributed evenly and then completely mixed into the corresponding experimental plots with a hand hoe down to 10 cm soil depth 21 days before planting (Okorogbona, et al., 2011; Mehdizadeh, et al., 2013). There

were 12 treatment combinations (Table 3). The plot size was 5 m × 5 m. The experimental design was a randomized complete block with three replicates. The experimental plot measured 75 x 20 m and consisted of three blocks. Each block measured 75 m x 5 m, and was divided into twelve plots. The plots measured 5 x 5 m each and adjacent plots were separated by an intervening space of 5 m, which allowed the movement of farm workers and the tractor.
The plot size was variable because of the width of the equipment and limited field space (6 to 8 m wide × 30 m long). The conventional tillage (CT) and no-till were performed on 24–30 May 2021 and 14–20 May 2022. As per treatment, the entire amounts of poultry manure and cow dung were applied 3 weeks before okra seeds were sown to the designated plots. The NPK 15:15:15 fertilizer was applied two weeks after okra seeds were sown to the appropriate plots used for the 2021 and 2022 cropping of okra.

Tab. 3 - Different treatments utilized in the study

Treatments	Description
AM (Amended plots)	
TRP	Plough + Poultry manure
SPP	Spray + Poultry manure
TCD	Plough + Cow manure
TRF	Plough + NPK 15:15:15
SPC	Spray + Cow manure
SLC	Slash + Cow manure
SPF	Spray + NPK 15:15:15
SLP	Slash + Poultry manure
SLF	Slash + NPK 15:15:15
NA (Non-amended plots)	
SLO	Slash Only
SPO	Plough Only
TRO	Plough Only

Crop establishment

On 30 May 2021 and 21 May 2022, an early maturing okra cultivar, T89KD-288, which takes 56–63 days to mature, was bought from the National Horticultural Research Institute of Ibadan, Nigeria for sowing. Three okra seeds were planted in each hole, with 0.6-meter distance between rows and 0.6-1 m spacing within rows. Two weeks after the seeds were sown, each stand was thinned to one plant, resulting in a plant population of roughly 27,778 plants ha^{-1}. For controlling insect pests, Ripcord @ 2 ml L^{-1} water was sprayed twice. Weeds were controlled manually with a hand hoe and by handpicking.

Soil moisture content determination and penetration resistance measurements

The moisture content in the soil was determined gravimetrically (Jabro et. al., 2015).

$$\text{Moisture content (\%)} = \frac{(\text{Wet soil weight}) - (\text{Oven-dried soil weight})}{\text{Oven-dried soil weight}} x\ 100 \qquad (1)$$

For the purpose of determining the gravimetric moisture content, five soil samples were randomly selected from each plot. A stainless-steel cone-tipped penetrometer (12.8 mm diameter, 30◦ cone soil compaction meter by Spectrum Technologies, Inc., Plainfield, IL) was pushed steadily into the soil to evaluate its strength. Moisture contents were determined at the time of soil strength measurements. The same operator performed all soil strength measurements for the two seasons in order to maintain an insertion rate as consistent as possible. Gravimetric moisture content (θm) and soil strength were measured three times during the growing season. Soil penetration readings were recorded in 7.5 cm increments to a depth of 30 cm. (7.5, 15, 22.5, and 30 cm) using a cone penetrometer (Eijkelkamp equipment type 1B) and at every three-week interval for 7 weeks during the two growing seasons: I two days after planting (1^{st} week), II at fully grown vegetation (4^{th} week), and III at the flowering stage (7^{th} week). Five soil crust strength measurements were taken at randomly selected positions in each plot.

Data on agronomic parameters (Determination of growth and yield parameters)

Fruit yields for each experimental plot were measured at the end of the crop lifespan as part of the data gathering process. When the okra reached physiological maturity, it was harvested. When the fruits were edible, they were picked every five days. Harvesting began on 20 July 2022 and ended on 10 August 2021; this was done again in 2022.

Data analysis

Data collected were subjected to the analysis of variance (ANOVA) to assess the treatments. Data were checked for normality and homogeneity of variances using Shapiro and Bartlett tests, respectively. The Duncan Multiple Range Test (DMRT) ($P = 0.05$) was used to differentiate mean differences SAS, 1999.

Results and Discussion

Selected physical and chemical properties of the soil

The experimental site's sandy loam surface soil (0–15 cm) had 740.0, 100.0, and 160.0 g kg^{-1} of sand, silt, and clay, respectively, whereas the sub-soil included 18, 10, and 72% of sand, silt, and clay, respectively (Table 1). The pH (water) of the soil was 6.39 for the depth of 0–15 cm and 6.31 for the depth of 15–30 cm. Okra grows best in the somewhat acidic soil (Sociedade Sul Brasileira de Arroz Irrigado [SOSBAI], 2016). Table 1 shows that the total N content of the top and sub-soil was 0.32% and 0.28%, respectively. These values were above the threshold value of 0.11 percent (Horneck et al., 2011) and adequate for okra development. The available P content was 10.68 ppm in the top soil and 10.24 ppm in the subsoil; both of these levels are over the critical value for the best crop development (Akinrinde & Obigbesan, 2000). There was enough organic matter in the top soil and subsoil layers to support an okra harvest.

Soil strength over the two cropping seasons

At the 5% probability level, tillage and soil amendment had a considerable impact on soil penetration resistance. The soil strength profiles under the two cropping seasons (2021-2022) to a 30-cm soil depth are presented in Fig. 1. The mean soil strength in the first cropping season for the twelve treatments in 2021 (1.59 MPa) was significantly greater than that in the second cropping season 2022 (1.30 MPa). This resulted in 18.2 % reduction in the average soil strength in the second cropping season between 0-30 cm soil depths (Fig. 1). The lower soil strength in 2022 could be attributed to soil amendment practices involved. It was also observed that the soil strength in amended (AM) experimental plots in 2021 and 2022 averaged 1.61 and 1.26 MPa, respectively, across the 0 to 30 cm depth range. The lower soil strength for the 2022 experimental plot was likely the result of soil loosening to a depth of 30 cm due to tillage and decomposition of materials used for soil amendment over time, as similar observation was reported by Shittu et al. (2023).

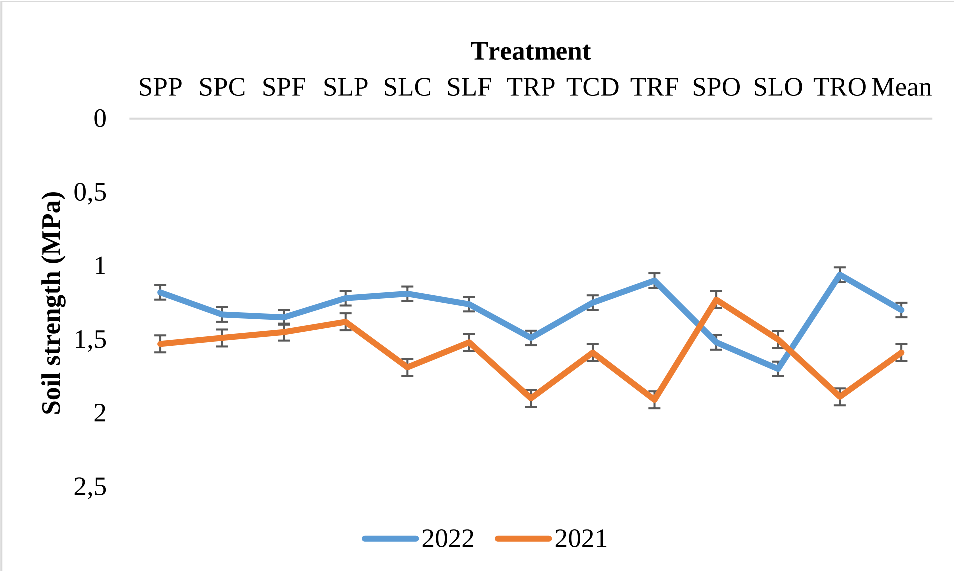


Fig. 1 - The impact of soil amendment and tillage on soil penetration resistance (PR) at depths of 0 to 30 cm. P = 0.05 indicates significance. Five measurements are averaged for each point. Two standard errors around the mean make up horizontal error bars.

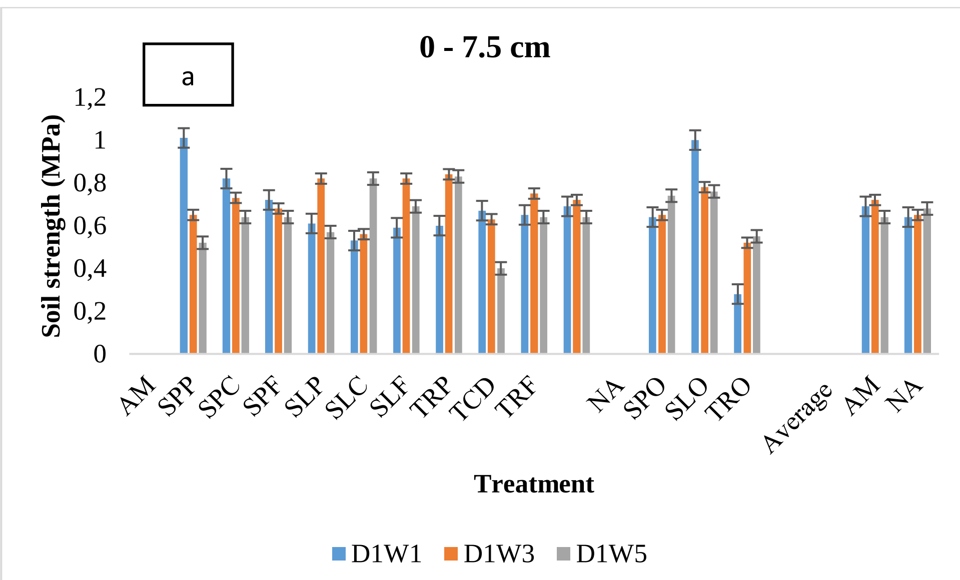
Soil strength at different soil depths under amended (AM) and non-amended (NA) experimental plots over the two seasons

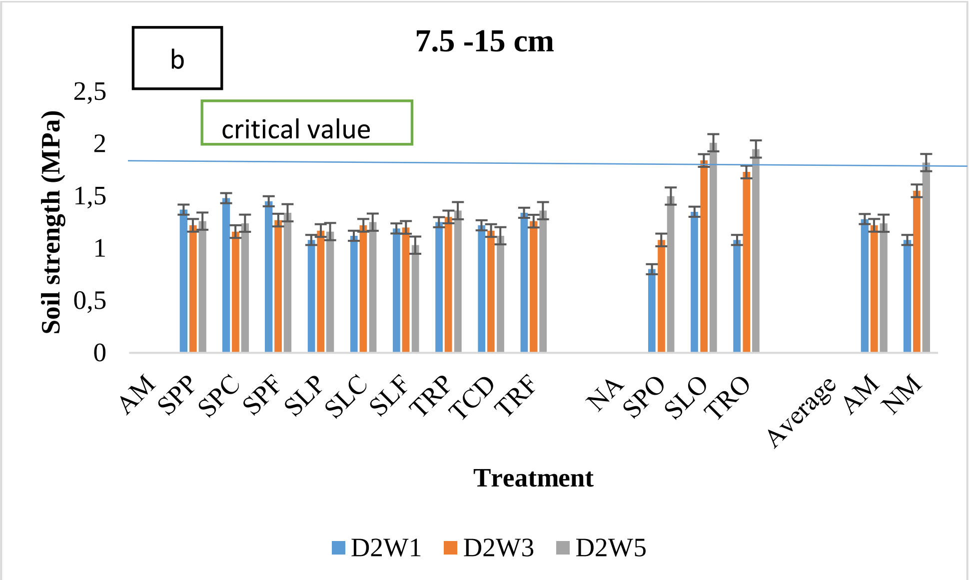
Tillage and soil amendment had a substantial impact on soil strength at the 0.05 probability level (Fig. 2a) in both amended and non-amended plots. Between 0-7.5 cm soil depth, averaged across two years, penetration under amended field treatments for weeks 1, 3, and 5 was 0.69, 0.72, and 0.64 MPa, respectively. The soil strength for non-amended plots over these weeks was 0.64, 0.65, and 0.6 8 MPa, respectively (Fig. 2a). The penetration resistance recorded for two different soil conditions considered was far below 2 MPa which can hinder the root growth of Okra. A similar observation was noticed between 7.5-15 cm soil depth. The soil strength ranged between 1.22 to 1.28 MPa in the AM plots while the NA plots had the lowest value (1.08 MPa) in the first week and the highest value of 1.82 MPa was significantly higher than any value recorded in the amended plots (Fig. 2b).

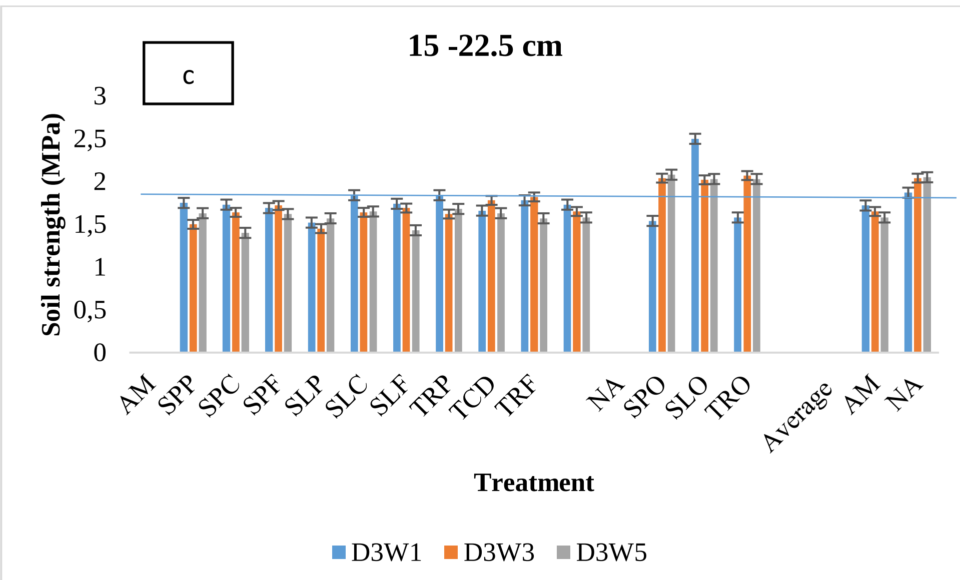
Between 15 and 22.5 cm soil depth, the soil strength in the amended experimental plots averaged 1.73, 1.65, and 1.58 MPa, respectively in the 1st 3rd, and 5th week. However, 1.87, 2.04, and 2.04 MPa which were significantly higher were obtained in the same period in the non-amended plots (Fig. 2c). Compared to a soil environment without amendment, soil amendment frequently creates healthier physical conditions that support a more favourable soil environment for plant growth. These findings concur with those of Khurshid et al. (2006), who found that, in comparison to tillage without soil amendment practices, tillage practices with amendments can result in the improved soil structure, reduced soil penetration resistance, and improved water percolation

Tillage with soil amendment had significant effects on lowering soil strength. The AM experimental plots with soil depth ranging between 22.5-30 cm had mean soil strength values of 1.98, 1.89, and 2.0 MPa at 1st, 3rd, and 5th, respectively, and were significantly lower than 2.08, 2.28, and 2.3 MPa recorded for the non-amended-plots at the same period (Fig. 2d). The soil amendment of the plots probably caused tillage-induced soil loosening, that is why the PR was lower in the amended experimental plots (Shittu et al., 2023; 2025), and all showed similar patterns in the soil strength with respect to tillage depth.

Higher soil strength values in the non-amended plots have resulted in mechanical resistance to root development compared with the amended plots (Picture 1 a–b). A similar observation was noticed for 22.5 to 30 cm soil depth where most soil strength in the NA plots (> 65%) had values that exceeded 2 MPa hindering the roots growth for appropriate absorption of mineral nutrients compared to the AM plots that had lesser PR percentage that exceeded this critical value (Fig. 2d).




b
7.5 -15 cm
critical value
Soil strength (MPa)
2,5
2
1,5
1
0,5
0
AM
SPP
SPC
SPF
SLP
SLC
SLF
TRP
TCD
TRF
NA
SPO
SLO
TRO
Average
AM
NM
Treatment
D2W1
D2W3
D2W5


c
15 -22.5 cm
Soil strength (MPa)
3
2,5
2
1,5
1
0,5
0
AM
SPP
SPC
SPF
SLP
SLC
SLF
TRP
TCD
TRF
NA
SPO
SLO
TRO
Average
AM
NA
Treatment
D3W1
D3W3
D3W5

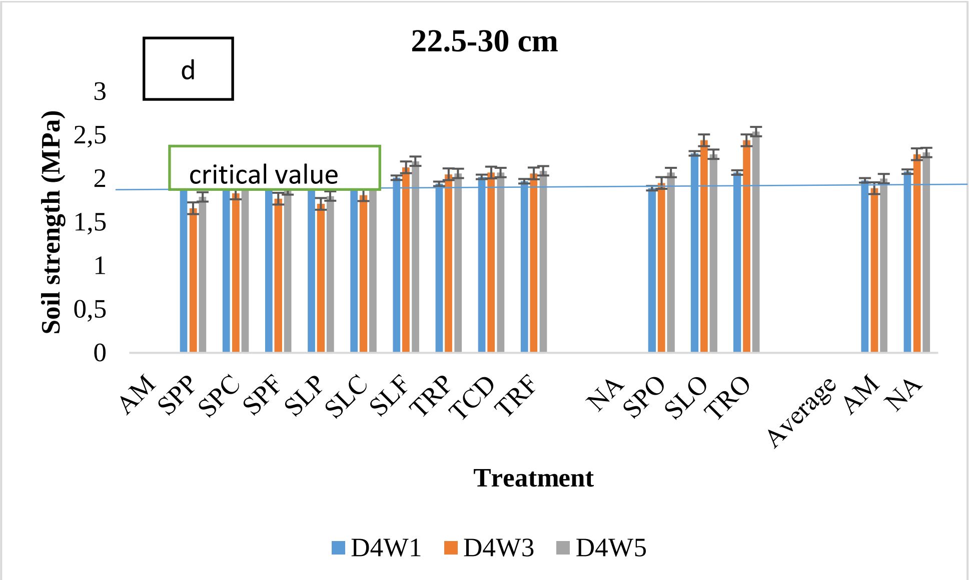


Fig. 2 (a, b, c, and d) - Soil strength at 0 to 30 cm depth as a function of tillage depth. The Duncan multiple range test, or DMRT, is significant at P = 0.05. Averaging ten measurements yields each point. There are two standard errors surrounding the mean in horizontal error bars.

D1 = 0 -7.5 cm, D2 = 7.5 - 15 cm, D3 = 15 – 22.5 cm, D4 = 22.5 -30 cm soil depth, W 1 = Week 1, W 3 = Week 3, W 5 = Week 5,

Picture 1a - Effect of tillage without soil amendment on shape and size of okra roots

Picture 1b - Effect of tillage and soil amendment on shape and size of okra roots

Gravimetric water content, θw in the AM and NA experimental plots

The θ_w was influenced by the tillage and soil amendment (Tables 4 and 5). Averages of θ_w at 0 to 15 cm depth in the AM and NA plots over the two cropping seasons were 12.31 and 8.38%, accounting for a 46.90% increase in the moisture content in the AM compared to the NA plots. The same trend was observed across the 15 to 30 cm soil depth; there were averages of 12.47 and 8.01% moisture content in the AM and NA, respectively, resulting in a 55.68 % increase in the available moisture in the AM when compared to the NA experimental plots. Addition of soil amendment significantly ($P \leq 0.05$) increased the moisture content of the soil (Tables 4 and 5), decreased the soil strength below a critical level (2 MPa) between 22.5 and 30 cm soil depth (Fig 2c) (which may lead to the increase in water percolation due to increasingly lower soil strength at deeper layers), and also improve the roots development for better nutrients absorption of okra (Picture. 1b). This is in line with results of Jabro et al. (2011). The addition of soil amendments improved soil properties such as water infiltration, reduced runoff, and increased water holding capacity, hydraulic conductivity, soil strength, and root penetration, also reported by Zaib et. al (2023). In the first week after sowing, the mean moisture content of treatments showed that there was no significant difference ($P>0.05$) in the moisture at 15 cm soil depth (Table 4). However, the average moisture content of the treatments during the 3rd week of sowing revealed that SLF (15.76%) had the highest moisture content and was significantly different from other treatments. The order of decreasing moisture content follows this pattern SLP ‘> SLC > TRF > TCD > SPP > SPF > TRP > SPC > SPO>TRO > SLO. In the 5th week of sowing, SLP with a moisture content of 15.08% from the AM treatment had the highest value and was significantly higher than SPO, SLO, and TRO (NA) by 128.5, 171.71, and 171.71%, respectively.

Tab. 4 - Moisture content at 0-15 cm soil depth for weeks 1, 3, and 5

Treatment	MCW1	MCW3	MCW5
	%		
	AM		
SPP	12.43^{a} 0.79	12.85^{ab} 0.78	10.73^{b} 0.90
SPC	11.50^{a} 1.05	10.91^{bc} 0.92	12.76^{ab} 1.17
SPF	11.07^{a} 1.27	12.84^{ab} 1.16	12.51^{ab} 0.97
SLP	12.912 1.34	14.640^{b} 1.84	15.08^{a} 2.13
SLC	13.26^{a} 1.03	13.25^{ab} 0.84	12.18^{ab} 1.48
SLF	11.31^{a} 1.23	15.79^{a} 1.76	11.97^{ab} 1.39
TRP	11.97^{a} 1.99	12.69^{ab} 0.97	11.63^{ab} 0.61
TCD	11.65^{a} 1.22	12.99^{ab} 1.01	9.58^{bc} 0.71
TRF	11.24^{a} 3.78	13.03^{ab} 1.00	9.78^{bc} 0.71
Mean/week	11.93	13.22	11.8
Mean AM/depth	12.31		
		NA	
SPO	10.45^{a} 2.01	9.82^{c} 1.57	6.60^{cd} 1.40
SLO	10.57^{a} 3.74	8.86^{c} 1.89	5.55^{d} 1.07
TRO	8.90^{a} 1.97	9.13^{c} 0.84	5.55^{d} 1.77
Mean/ week	9.97	9.27	5.9
Mean NA/depth	8.38		

MC = Moisture content; W1 = Week 1, W3 = Week 3, W5 = Week 5; Means followed by the same letter in a column are not significantly different at the 5% level by DMRT.

Between 15-30 cm soil depth (Table 5), SLC and SLF from the AM treatments had the highest value and were significantly different from other treatments in the NA experimental plots. The addition of soil amendment improved soil properties such as the soil strength (Fig. 1) and water-holding capacity, this being in line with what Jayasinghe et al (2010) reported.

Tab 5. - Moisture content at 15–30 cm soil depth for week 1, 3, and 5

Treatment	MCW1	MCW3	MCW5
	%		
	AM		
SPP	12.60^{ab} 0.38	12.37^{ab} 1.00	12.07^{a} 0.40
SPC	12.63^{ab} 0.57	11.54^{abc} 0.89	11.32_{a} 0.17
SPF	12.12^{ab} 0.78	13.26^{a} 0.66	13.39^{a} 0.46
SLP	12.31^{ab} 0.77	12.35^{ab} 1.11	13.51^{a} 1.00
SLC	14.39^{a} 1.33	13.57^{a} 0.47	12.36^{a} 1.25
SLF	14.39^{a} 0.80	14.02^{a} 0.95	11.79^{a} 0.85
TRP	11.64^{abc} 0.60	13.36^{a} 0.62	11.50^{a} 0.43
TCD	12.34^{ab} 0.81	11.69^{ac} 1.70	10.95^{a} 0.65
TRF	11.96^{ab} 0.57	12.79^{ab} 0.35	10.61^{a} 0.31
Mean/week	12.71	12.77	11.94
Mean AM/depth	12.47		
	NA		
SPO	9.29^{bc} 1.83	8.57^{bc} 1.37	6.63^{b} 1.18
SLO	9.07^{bc} 1.66	9.99^{abc} 3.67	6.11^{b} 1.19
TRO	8.33^{c} 1.92	7.74^{c} 1.16	6.38^{b} 1.66
Mean/ week	8.9	8.77	6.37
Mean NA/depth			8.01

MC = Moisture content; W1 = Week 1, W3 = Week 3, W5 = Week 5; Means followed by the same letter in a column are not significantly different at the 5% level by DMRT.

Average okra yield over the two growing seasons

Okra yield was significantly affected by tillage coupled with soil amendment, while TRP (1.45 tons/ha) on one of the AM plots had the highest yield and was significantly greater than SPO (0.15 tons/ha) and SLO (0.13 tons/ha) on the NA plots by 867 and 1015%, respectively, at the 0.05 probability level (Fig. 3). Okra yield was greater under the AM than under the NA experimental plots (Fig. 3). Variations in the soil strength, moisture content, and root shape may have contributed to the significant disparity in the okra output between the AM and NA treatments. When paired with the appropriate soil amendment, tillage improves soil conditions more than tillage alone because it loosens the soil, which promotes deeper root movement in the soil profile, increases root depth and development, and enhances water intake rate (Picture 1a). Furthermore, the decrease in okra production in the non-amended (NA) treatment (Fig. 3) and improvement in the root morphology of okra in the amended plots (AM) may be related to lower moisture content at the active rooting zone (Fig. 2c-d) and increased soil strength (Akram et al., 2024).

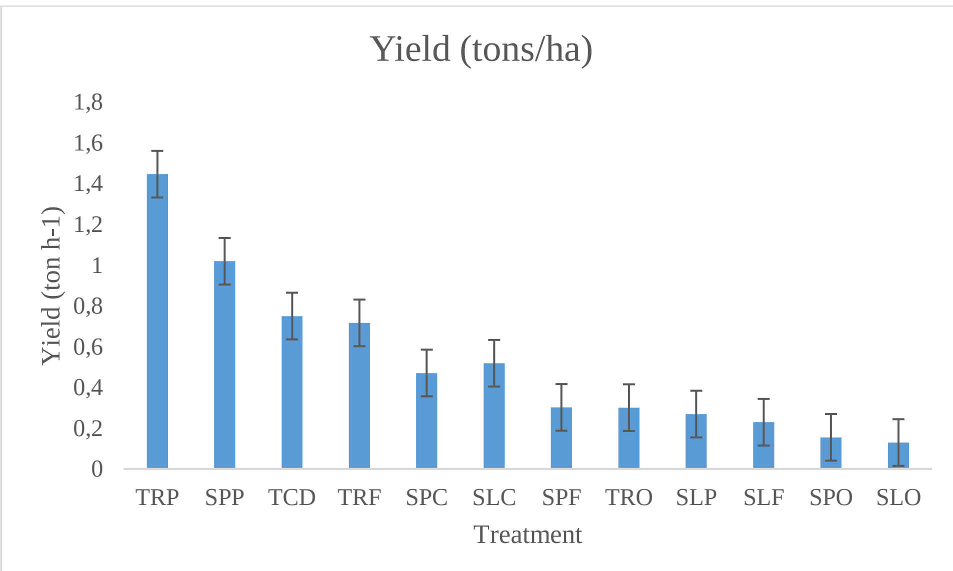


Fig. 3 - Okra yield under tillage with soil amendment (AM) and tillage without amendment (NA) for 2021 and 2022 and their average across two years. Error bars indicate two standard errors around the mean of measured values or 95% confidence interval.

Conclusion

The impact of tillage with soil amendment on soil strength and moisture content on okra yield was assessed in this study. Tillage had a major impact on the moisture content and strength of the soil. At the 15 to 30 cm depth where most of the active roots are residing, the non-amended experimental plots had higher values than the amended plots, whereas the AM experimental plots had higher moisture content than the NA experimental plots at this soil depth. The AM treatments increased the available water for growth and development and possibly decreasing soil penetration resistance. Soil amendment often provides healthier soil physical conditions that promote a more favourable soil environment for plant growth relative to a non-amended soil environment. A conclusion can be drawn that tillage practices coupled with soil amendment have enhanced selected soil physical qualities and okra yield at the 0.05% probability level. It can also be concluded from the trial conducted that conventional tillage coupled with poultry and animal manure will not only produce higher quantity of okra yield but also promote the physical health of soil.

References

Akinrinde, E. A., & Obigbesan, G. O. (2000). Evaluation of the fertility status of selected soils for crop production in five ecological zones of Nigeria. In Soil Science Society of Nigeria (Ed.), *Proceedings of the 26th Annual Conference of Soil Science Society of Nigeria, Ibadan, Nigeria* (pp. 279–288). Soil Science Society of Nigeria.

Akram, M. Z., Rivelli, A. R., Libutti, A., Liu, F., & Andreasen, C. (2024). Mitigation of drought stress for Quinoa (*Chenopodium quinoa* Willd.) varieties using woodchip biochar-amended soil. *Plants*, 13(16), 2279. https://doi.org/10.3390/plants13162279

Angon, P. B., Anjum, N., Akter, M. M., KC, S., Suma, R. P., & Jannat, S. (2023). An overview of the impact of tillage and cropping systems on soil health in agricultural practices. *Advances in Agriculture*, (1), 8861216. https://doi.org/10.1155/2023/8861216

Bennett, J. G. (1980). Aeolian deposition and soil parent material in northern Nigeria. *Geoderma*, 24, 241-255. https://doi.org/10.1016/0016-7061(80)90027-0

Farahani, E., Emami, H., & Forouhar, M. (2022). Effects of tillage systems on soil organic carbon and some soil physical properties. *Land Degradation & Development*, 33(8), 1307-1320. https://doi.org/10.1002/ldr.4221

Hamza, M. A., & Anderson, W. K. (2005). Soil compaction in cropping systems. A review of the nature, causes and possible solutions. *Soil and Tillage Research*, 82(2), 121–145. https://doi.org/10.1016/j.still.2004.08.009

Horneck, D. A., Sullivan, J. S., Owen, J. S. & Hart, J. M. (2011). *Soil test interpretation guide*. Oregon State University. https://catalog.extension.oregonstate.edu/ec1478

Ismail, C., Hikmet, G., Mesut, B., & Cagda, A. (2010). Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. *Geoderma*, 160(2), 236–243. https://doi.org/10.1016/j.geoderma.2010.09.028

Jabro, J. D., Stevens, W. B., Iversen, W. M., & Evans, R. G. (2011). Bulk density and hydraulic properties of a sandy loam soil following conventional or strip tillage. *Applied Engineering in Agriculture*, 27(5), 765–768. https://doi.org/10.13031/2013.39576

Jayasinghe, G. Y., Tokashiki, Y., Kitou, M., & Kinjo, K. (2010). Effect of Synthetic Soil Aggregates as a Soil Ameliorant to Enhance Properties of Problematic Gray (''Jahgaru'') Soils in Okinawa, Japan. *Communications in Soil Science and Plant Analysis*, 41(5), 649–664 https://doi.org/10.1080/00103620903533959

Jabro, J. D., William, M., Iversen, W. B., Stevens, R. G., Evans, M. M., & Brett, L. A. (2015). Effect of Three Tillage Depths on Sugarbeet Response and Soil Penetrability Resistance. *Agronomy Journal*, 107(4), 1481–1488. https://doi.org/10.2134/agronj14.0561

Khurshid, K., Iqbal, M., Arif, M.S., & Nawaz, A. (2006). Effect of tillage and mulch on soil physical properties and growth of maize. *International Journal of Agriculture & Biology*, 8(5), 593–596. https://api.fspublishers.org/viewPaper/5034_..pdf

Mehdizadeh, M., Darbandi, E. I., Naseri-Rad, H., & Tobeh, A. (2013). Growth and yield of tomato (*Lycopersicon esculentum* Mill.) as influenced by different organic fertilizers. *International Journal of Agronomy and Plant Production*, 4, 734-738 https://www.cabidigitallibrary.org/doi/pdf/10.5555/20133138185

Okorogbona, A. O. M., Van, A. W., & Ramusandiwa, T. D. (2011). Growth and yield response of Chinese cabbage (*Brassica rapa* L. *subsp. chinensis*) as affected by nutrient availability in air-dried and pulverized different types of animal manure using low biological activity soil. *World Journal of Agricultural Sciences*, 7, 1–12. https://www.cabdirect.org/cabdirect/abstract/20113169894

Šarauskis, E., Sokas, S., & Rukaitė, J. (2024). Variable Depth Tillage: Importance, Applicability, and Impact—An Overview. *AgriEngineering*, 6(2), 1870-1885. https://doi.org/10.3390/agriengineering6020109

SAS Institute. (1999). *Statistic users' guide: Basics* [1990 ed] (pp. 891-996). SAS Institute.

Shahane, A. A., & Shivay, Y. S. (2021). Soil health and its improvement through novel agronomic and innovative approaches. *Frontiers in Agronomy*, 3, 680456. https://doi.org/10.3389/fagro.2021.680456

Shaheb, M. R., Venkatesh, R., & Shearer, S. A. (2021). A review on the effect of soil compaction and its management for sustainable crop production. *Journal of Biosystems Engineering*, 46(4), 417-439. https://doi.org/10.1007/s42853-021-00117-7

Shittu, K. A., Adeboye, O. B., Oyedele, D. J., Agunbiade, W. L., Babatunde, K. M., & Murtadha, A. M. (2023). Impact of tillage practices on properties of soil, evapotranspiration and productivity of cowpea in Nigeria. *Tropical and Subtropical Agroecosystems*, 26(1), 30. http://doi.org/10.56369/tsaes.4401

Shittu, K. A., Adeboye, O. B., Oladiran, F. V., Azeez, M. O., Are, K. S., & Adisa, K. F. (2025). Impact of Tillage Practices and Soil Amendments on Soil Strength and Yield of Okra (*Abelmoschus esculentus* (L.) Moench) in Nigeria. *Tanzania Journal of Science*, 51(2), 380-393. https://doi.org/10.4314/tjs.v51i2.10

Sociedade Sul Brasileira de Arroz Irrigado [SOSBAI]. (2016). *Arroz Irrigado: Recomendações técnicas da pesquisa para o sul do Brasil [Irrigated Rice: Technical Recommendations of the Research for Southern Brazil]* (p. 200). SOSBAI.

Syromyatnikov, Y., Troyanovskaya, I., Zagidullin, R., Tikhonov, E., Orekhovskaya, A., & Voinash, S. (2023). Soil density in traditional mouldboard tillage, *Acta Technologica Agriculturae*, 26(3), 159-165. https://doi.org/10.2478/ata-2023-0021

Thomas, P., Mondal, S., Roy, D., Meena, M., Aggarwal, B., Sharma, A., & Chakraborty, D. (2020). Exploring the relationships between penetration resistance, bulk density and water content in cultivated soils. *Journal of Agricultural Physics*, 20(1), 22-29. https://www.agrophysics.in/admin/adminjournalpdf/202012021014451348889434/journal-182610965.pdf

Zaib, M., Raza, I., Zubair, M., Arif, Z., Mumtaz, M. M., Abbas, M. Q., & Uzair, M. (2023). Nano-enabled soil amendments for improved soil structure and water holding capacity: an in-depth review. *International Research Journal of Education and Technology*, 5(08), 344-357. https://www.irjweb.com/viewarticle.php?aid=Nano-Enabled-Soil-Amendments-for-Improved-Soil-Structure-and-Water-Holding-Capacity%3A-An-In-depth-Review

Zhang, L., Sun, J., & Shi, C. (2024). Numerical simulation on the influence of plant root morphology on shear strength in the sandy soil, Northwest China. *Journal of Arid Land*, 16(10), 1444-1462. https://doi.org/10.1007/s40333-024-0030-2

Утицај побољшања земљишта на удио влажности, чврстоћу земљишта и принос бамије гајене на глинасто пјесковитом земљишту у југозападној Нигерији

Shittu K. A.[1], Adeboye O. B. [2], Oladiran F. V. [1]

[1] Државни универзитет Осун, Пољопривредни колеџ, Факултет за пољопривредну производњу и менаџмент, Осогобо, Држава Осун, Нигерија
[2]Универзитет Обафеми Аволово, Технолошки факултет, Иле-Ифе, Нигерија

Сажетак

Посљедице неправилне обраде и управљања земљиштем огледају се у мањем квалитету земљишта и смањеном приносу. Циљ овог истраживања је да пружи информације о одговарајућој обради и мјерама за побољшање земљишта које не само да могу унаприједити квалитету земљишта него и допринијети оптималној производњи бамије на одрживи начин. Спроведено је двогодишње истраживање у току кишне сезоне 2021. и 2022. године на Фарми за наставу и истраживање, Ејигбо кампус, Ејигбо, држава Осун, Нигерија. Коришћене су три опције за припрему земљишта, укључујући сљедеће: I. ручно уклањање остатака претходних култура и корова, II. ручно прскање глифосатом и III. конвенционална обрада. Примијењена су три различита начина прихране. Удио влажности у земљишту је одређен гравиметријски, а сабијеност земљишта измјерена је одмјереном апликацијом пенетрометра са конусним врхом од нерђајућег челика (пречника 12,8-mm, 30◦ конус) у земљиште. Средње вриједности чврстоће земљишта од 1,65 и 1,98 MPa забиљежене су за побољшану гредицу и непобољшане гредице, што је за резултат имало 16,7% смањене чврстоће земљишта у поређењу са непобољшаним експерименталним гредицама. Такође, средње вриједности чврстоће земљишта у току прве сезоне узгоја за дванаест третмана у 2021. години (1,59 MPa) биле су знатно веће него у другој сезони узгоја 2022. године (1,30 MPa). То је за резултат имало смањење од 18,2% у просјечној чврстоћи земљишта у другој сезони узгоја на дубини земљишта од 0 до 30 cm. TRP (1,45 tona/ha) на једној од побољшаних гредица имала је највиши принос и била је знатно већа од SPO (0,15 tona/ha) и SLO (0,13 tona/ha) на непобољшаним гредицама за 867 и 1015% на нивоу вјероватноће од 0,05. У поређењу са условима непобољшаног земљишта, побољшање земљишта често доводи до бољих физичких особина које пружају повољније окружење за раст биљака.

Кључне ријечи: Релативна влажност, Конвенционална обрада, Чврстоћа земљишта, Прскање, Обрада земљишта.

Corresponding author: O. B. Adeboye
E–mail: adeboyeob@oauife.edu.ng

Received: April, 04, 2025
Accepted: July 08, 2025