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Effects of soil amendments on selected soil physical properties and okra (*Abelmoschus esculentus L. Moench)* yield in Southwest Nigeria

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Abstract

A two-year study was conducted during in the wet season of 2021 and 2022 at the Teaching and Research Farm, Ejigbo Campus, Ejigbo, Osun State, Nigeria to evaluate the effects of soil amendment on moisture content, soil strength and okra yield. The study included the following treatments: (i) slashing with cutlass, (ii) manually spraying with glyphosate, and (iii) conventional tillage. The moisture content in soil was determined gravimetrically. The soil strength of 1.65 and 1.98 MPa were recorded for amended (AM) and non-amended (NA) treatment plots respectively, which resulted in 16.7% decrease in soil strength when compared with NA experimental plots. The mean soil strength during the first cropping season in 2021 (1.59 MPa) was significantly higher than in the second cropping season in 2022 (1.30 MPa), resulting in an 18.2% reduction in average soil strength between 0–30 cm soil depth. AM plots achieved the highest yield, significantly exceeding the yield of treatment plots where weeds were sprayed with herbicide (SPO, 0.15 tons/ha) and those where vegetation was slashed with a cutlass (SLO, 0.13 tons/ha) without amendment – by 867% and 1015%, respectively, at the 0.05 probability level. Soil amendments generally enhance soil physical conditions, creating a more favorable environment for plant growth compared to non-amended soil.

***Keywords*: c**onventional tillage, soil strength, spraying, land preparation, soil amendment

INTRODUCTION

Soil tillage is an important agronomic practice that requires significant expense and high-energy inputs. It is carried out to establish favourable soil conditions for plant growth and development (Badalikova, 2010). Further, tillage is one of the most influential agricultural management practices, capable of altering soil's physical, chemical, and biological properties, thereby affecting crop yield and quality (Strudley et al., 2008). Selecting the appropriate tillage type and depth is important for maintaining soil quality necessary for successful crop growth (Lal & Shukla, 2004; Hamza & Anderson, 2005).

Tillage systems induce changes in soil penetration resistance, bulk density, aggregate stability and soil water storage (Jabro et al., 2011). Reduced tillage and no-tillage systems usually increase aggregate stability, and infiltration rate, and improve water storage due to increase organic matter in the soil (Hao et al., 2000). The most common indices used to determine soil strength in tillage studies are penetration resistance (PR) and bulk density. Soil compaction, which depends on the type of implement used, depth of soil disturbance and tillage method (Hamza & Anderson, 2005) is typically quantified by PR. Therefore, assessing the effect of tillage depth on soil compaction can clearly explain the differences in crop growth, development, yield and quality. In most cases, all tillage methods reduced soil penetration resistance to the depth of tillage (Lampurlanes & Cantero-Martinez, 2003; Jabro et al., 2010; Gathala et al., 2011). Strong compaction occurs when heavy combine harvesters and transport vehicles are used in soils with high level of wetness. Soil compaction effects are long-lasting or even permanent, particularly in soils with a low clay content (Håkansson & Lipiec 2000). 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 a decrease length, abundance of roots in the top layer and decreasing rooting depth (Medvedev et al., 2000). Soil bulk density, PR, and water movement in the soil, all indices of soil compactness and porosity, depend on depth and method of tillage (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 resulted from 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 the various tillage operations along with good soil amendments. Successful study can lead to improvement in production of food in sustainable form and also improve soil health in the long run. The objective of this study was to assess the impact of soil amendment on moisture content, penetration resistance and yield of okra in South-western Nigeria.

MATERIALS AND METHODS

Site and soil description

The study was conducted in the wet season of 2021 and 2022 at the Teaching and Research Farm, Ejigbo Campus, Ejigbo, Osun State, Nigeria. The facility is located at 7º 52' 19" N, E 004° 18' 28" within the Derived savannah zone of southwest Nigeria. Ejigbo, a town in Osun State belongs to this agro-ecological zone. Before the experiment commenced in 2021, soil samples were randomly collected from ten points across the site. The soil samples were mixed, air-dried and passed through a 2-mm sieve before analysis. The Derived Savannah is characterized by a growing period lasting between 7 and 9 months (Salako, 2006) The soils at Ejigbo are developed from crystalline Basement Complex rocks (granites, gneisses and schists) (Bennet, 1980), which is the dominant parent material in Nigeria. There are two rainy seasons, one from March to July and the second from mid-August to November. The climate is hot and humid having dry and rainy seasons. Annual rainfall of approximately 950 mm, with an average humidity of 70.30%. The maximum temperature reaches 32.80°C, while the minimum temperature is 20.83°C. Predominant weeds at the site of the experiment were siam weed (*Chromolaena odorata L*. King and Robinson), haemorrhage plant (*Aspilia africana* Pers. Adam) and broom weed (*Sida acuta* Burm).

Three tillage practices were used: slashing with cutlass, manual glyphosate spraying and conventional tillage (two ploughing passes followed by one harrowing). Seven days after the initial plough on designated experimental plots, a second ploughing was conducted. The maximum tillage depth was 20 cm. Three nutrient management strategies were applied: cow dung and poultry manure at equal rates (12.5 t ha^{-1} yr^{-1}, dry weight) (Ismail et al., 2010), and chemical fertilizer (NPK 15:15:15) at 100 kg ha^{-1}. Additionally, three control plots were maintained without nutrient amendments (SPO, SLO and TRO – Table 2).

Soil samples from depths of 0–15 cm and 15–30 cm were collected one week before the start of the 2021 growing season. Standard procedures were followed to collect and sub-sample composite soil samples at each depth for the determination of specific physical and chemical soil parameters. Table 1 presents the physiochemical characteristics of the soil used in the study. The same location was utilized for okra cultivation in both the 2021 and 2022 growing seasons.

Table 1. Selected soil parameters (2021-2022)

Soil Parameter	**Soil Depth**	
	0-15 cm	15-30 cm
Clay (%)	16	72
Silt (%)	10	10
Sand (%)	74	18
Texture*	Sandy loam	Clay
Organic matter (%)	3.1	3.0
Total N (g kg^{-1})	3.2	2.8
pH (H_2O)	5.4	5.3

Legend: * The texture class according to USDA

Cattle manure from a local smallholder farmer and poultry manure from the broiler house at Osun State University in Ejigbo) were used as organic manure. The manure was carefully mixed, and larger particles were manually removed. It was then evenly distributed and thoroughly mixed into the corresponding experimental plots with a hand hoe to a depth of 10 cm soil depth, 14 days before planting (Okorogbona, *et al.*, 2011; Mehdizadeh, et al., 20013). There were 12 treatment combinations (Table 2). The plot size was 3 m × 3 m. The experimental design followed a randomized complete block with three replicates. Plot size varied due to equipment width and limited field space (6 to 8 m wide × 30 m long). Conventional tillage (CT) and no-till were implemented from 24–30 May 2021 and 14–20 May 2022. As per treatment specifications, poultry manure and cow dung were applied three weeks before okra seeds were sown in the designated plots. The NPK 15:15:15 fertilizer was applied two weeks after sowing in the appropriate plots

The early-maturing okra variety IT89KD-288, which takes 56–63 days to mature, was obtained from the National Horticultural Research Institute in Ibadan and sown on 1st September 2021 and 7th September 2022. Three seeds of okra were sown per hole at an inter-row spacing of 0.6 m and an intra-row spacing of 0.6 m. Two weeks after sowing, thinning was carried out, leaving one plant per stand, resulting in a plant population of approximately 27,778 plants ha^{-1}. To control insect pests, Ripcord at 2 ml L^{-1} of water was sprayed twice. Weeds were managed manually using a hand hoe and handpicking.

Table 2. Different treatments utilized in the study

Treatment	**Description**
AM	
TRP	Plough + Poultry manure
SPP	Spray + Poultry manure
TCD	Plough + Cow dung
TRF	Plough + NPK 15 15 15
SPC	Spray + Cow dung
SLC.	Slash + Cow dung
SPF	Spray + NPK 15 15 15
SLP	Slash + Poultry manure
SLF	Slash + NPK 15:15:15
NA	
SLO	Slash Only
SPO	Spray Only
TRO	Plough Only

Legend: AM – Amended plots, NA – Non-amended plots

The moisture content in soil was determined gravimetrically, Jabro *et.al.*, 2015.

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

Five soil samples were randomly taken from each plot for gravimetric moisture content estimation. Soil strength was measured by pushing a stainless-steel cone-tipped penetrometer (12.8 mm diameter, 30° cone, Soil Compaction Meter; Spectrum Technologies, Inc., Plainfield, IL) into the soil at a steady rate. At the time of the soil strength measurements, moisture contents were determined. Soil strength and gravimetric moisture content (θ_m) were measured thrice over the growing season. The same operator conducted all soil strength measurements for the two seasons to maintain an insertion rate, as uniform as possible. 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 and at every three weeks intervals for 7 weeks during the two growing seasons: (i) two days after planting (1st week), (ii) at fully grown vegetation (4th week) and (iii) at the fruiting stage (7th week). Five soil crust strength measurements were taken at randomly selected positions in each plot.

Data collection on agronomic parameters involved measurement of fruit yields at the end of the crop lifecycle for all the experimental plots. At physiological maturity, okra fruits were harvested at five-day interval at the edible stage. Harvesting started from 25th October, 2021 and ended on 24th November, 2021, this was repeated in the year 2022.

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

RESULTS AND DISCUSSION

The surface soil (0-15 cm) of the experimental site was sandy loam, comprising 74% sand, 10% silt and 16% clay, while the sub-soil contained 18% sand, 10% silt and 72 % clay (Table 1). The soil pH (in water) at a depth of 0-15 cm was 5.4, while at 15-30 cm was 5.3. The soil was slightly acidic and suitable for optimal okra growth (SOSBAI, 2016). The total N content of the topsoil and sub-soil was 3.2 and 2.8 g kg^{-1}, respectively – both exceeding the critical value of 0.11 % (Horneck et al., 2011) sufficient for okra growth (Table 1). Available P was 10.68 ppm in the top soil and 10.24 ppm in the sub-soil, both above the critical level for optimum crop growth (Akinrinde & Obigbesan, 2000). The topsoil and sub-soil layers contained an adequate amount of organic matter to sustain okra cultivation.

Soil strength of two cropping seasons

The effect of tillage and soil amendment on soil penetration resistance was significant at the 5% probability level. The soil strength profiles under two cropping seasons (2021-2022) to a 30-cm soil depth are presented in Figure 1. The mean soil strength under first cropping season for the twelve treatments in 2021 (1.59 MPa) was significantly higher than that during second cropping season 2022 (1.30 MPa). This resulted into 18.2% reduction in average soil strength in the second cropping season at soil depth of 0 to 30 cm (Fig.1). The lower soil strength in 2022 could be attributed to applied soil amendment practices. It was also observed that soil strength in amended experimental plots (AM) in 2021 and 2022 averaged 1.61 and 1.26 MPa, respectively, at soil depth of 0 to 30 cm.

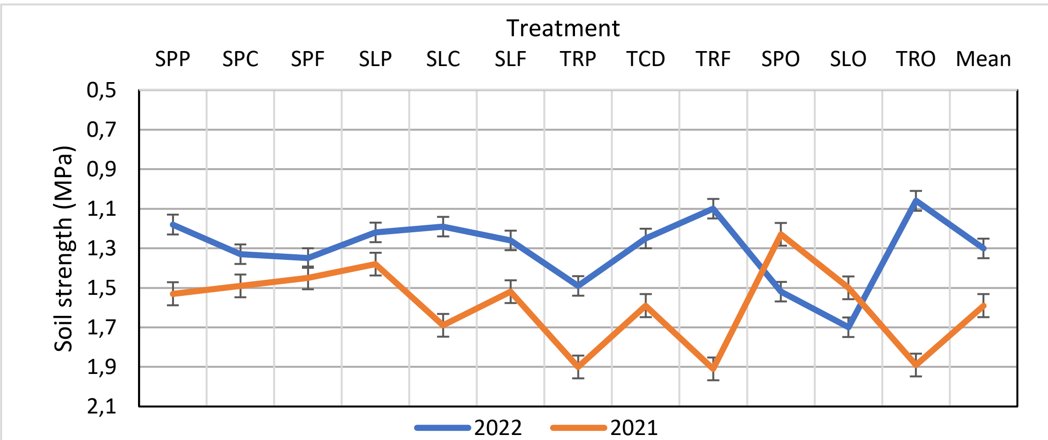

Figure 1. Effect of tillage and amendments on soil penetration resistance (PR) at depth of 0 to 30 cm

The lower soil strength in the 2022 experimental plot was likely due to soil loosening to a depth of 30 cm from tillage and the incorporation of soil amendment materials, which later assimilated into the top layer. A similar observation was reported by Shittu et al. (2023).

Gravimetric Water Content, θ_w in AM and NA Experimental plots

The θ_w was influenced both by tillage and soil amendment (Table 3). The average values of θ_w at 0- to 15-cm depth in AM and NA plots over the two cropping seasons were 12.31 and 8.38%, respectively. This accounted for a 46.90% increase in the moisture content in AM compared with NA plots. The same trend was observed at soil depth of 15 to 30 cm, there were average values of 12.47 and 8.01% moisture content in AM and NA, respectively, resulted in a 55.68% increase in available moisture in AM in comparison to NA experimental plots. Soil amendments significantly ($p < 0.05$) increased the soil moisture content (Table 3) and improved soil properties ($p < 0.05$) such as water-holding capacity, hydraulic conductivity, soil strength and root penetration. Similar observations were reported by (Franzluebbers, 2002) and Jabro et al. (2015).

In the first week after sowing, the mean moisture content of treatments did not show a significant difference ($p < 0.05$) at a soil depth of 15 cm. However, by the third week, SLF (15.76%) had the highest moisture content and was significantly different from other treatments. The order of decreasing moisture content follows the pattern: SLP > SLC > TRF > TCD > SPP > SPF > TRP > SPC > SPO > TRO > SLO. By the fifth week after sowing, SLP, with a moisture content of 15.08% from 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. Between the 15–30 cm soil depth, SLC and SLF from AM treatments had the highest values and were significantly different from other treatments in NA experimental plots. The addition of soil amendments improved soil properties such as soil strength (Fig. 1) and water-holding capacity, aligning with the findings of Jayasinghe et al. (2010).

Average okra yield over the two growing seasons

Okra yield was significantly affected by tillage coupled with soil amendment. TRP (1.45 tons/ha), 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) NA plots by 867% and 1015%, respectively, at the 0.05 probability level (Figure 2). Okra yield was higher under AM than under NA experimental plots. The substantial difference in okra yield between AM and NA treatments may be attributed to variations in soil strength and moisture content (Table 3).

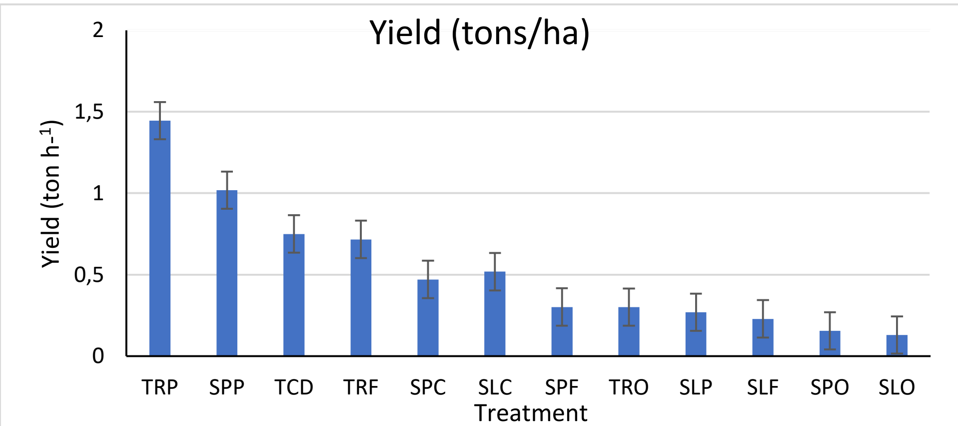

Figure 2. Average okra yield under tillage with and without soil amendments for two cropping seasons (2021 and 2022)

Table 3: Moisture content at different soil depths and weeks after sowing

Treatment	MCW1 D15 cm	MCW3 D15 cm	MCW5 D15 cm	MCW1 D30 cm	MCW3 D30 cm	MCW5 D30 cm
			(%)			
AM						
SPP	12.43a ± 0.79	12.85ab ± 0.78	10.73b ± 0.90	12.60ab ± 0.38	12.37ab ± 1.00	12.07a ± 0.40
SPC	11.50a ± 1.05	10.91bc ±0.92	12.76ab ± 1.17	12.63ab ± 0.57	11.54abc ± 0.89	11.32a ± 0.17
SPF	11.07a ± 1.27	12.84ab ± 1.16	12.51ab ± 0.97	12.117ab ± 0.78	13.26a ± 0.66	13.39a ± 0.46
SLP	12.912 ± 1.34	14.640b ± 1.84	15.08a ± 2.13	12.310ab ± 0.77	12.35ab ± 1.11	13.51a ± 1.00
SLC	13.26a ± 1.03	13.25ab ± 0.84	12.18ab ± 1.48	14.39a ± 1.33	13.57a ± 0.47	12.36a ± 1.25
SLF	11.31a ± 1.23	15.79a ± 1.76	11.97ab ± 1.39	14.39a ± 0.80	14.02a ± 0.95	11.79a ± 0.85
TRP	11.97a ± 1.99	12.69ab ± 0.97	11.63ab ± 0.61	11.64abc ± 0.60	13.36a ± 0.62	11.50a ± 0.43
TCD	11.65a ± 1.22	12.99 ab ± 1.01	9.58bc ± 0.71	12.34ab ± 0.81	11.69ac ± 1.70	10.95a ± 0.65
TRF	11.24a ± 3.78	13.03ab ± 1.00	9.78bc ± 0.71	11.96ab ± 0.57	12.79ab ± 0.35	10.61a ± 0.31
Mean/week	11.93	13.22	11.8	12.71	12.77	11.94
Mean AM/depth			12.31			12.47
Total Mean AM	**12.39**					
NA						
SPO	10.45a ± 2.01	9.82c 1.57	6.60cd 1.40	9.29bc 1.83	8.57bc 1.37	6.63b 1.18
SLO	10.57a ± 3.74	8.86c ± 1.89	5.55d ± 1.07	9.074bc ± 1.66	9.99abc ± 3.67	6.11b ± 1.19
TRO	8.904a ± 1.97	9.13c ± 0.84	5.55d ± 1.77	8.33c ± 1.92	7.74c ± 1.16	6.38b ± 1.66
Mean/ week	9.97	9.27	5.9	8.9	8.77	6.37
Mean NA/depth			8.38			8.01
Total Mean NA	**8.20**					

Legend: MCW1 = Moisture content at week 1; MCW3 = Moisture content at week 2; MCW5 = Moisture content at week 3; D 15 cm = 15 cm soil depth; D 30 cm = 30 cm soil depth

Tillage with appropriate soil amendment improves soil conditions more effectively than tillage alone, as it loosens the soil, enhances water intake rate, and increases root depth and development, allowing for deeper root penetration in the soil profile (Richard et al., 1995).

CONCLUSIONS

This study evaluated the effects of tillage with soil amendment on soil strength and moisture content in relation to okra yield. Soil strength and moisture content were significantly affected by tillage. Soil strength was greater in non-amended than in amended experimental plots at the 15–30 cm depth, where the active roots reside, whereas moisture content was higher in AM than in NA treatments. The AM treatments increased the available water for growth and development, possibly decreasing soil penetration resistance. Soil amendment often provides healthier soil physical conditions, promoting a more favorable soil environment for plant growth compared to non-amended soil. It was concluded that tillage practices, coupled with soil amendment, enhanced selected soil physical properties and improved okra yield at the 0.05 probability level.

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