Finite modeling of growth and yield of okra using different tillage systems

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Abstract: Field experiment conducted was aimed to model the okra growth and yield using different tillage systems. Randomised complete block design (RCBD) was used with three treatments and three replicates. Treatments were conventional-ploughing and harrowing (A), conservative (B) and zero tillage (C). Each treatment had three replicates of area 8 m × 8 m, separated from each other by 2 m for manoeuvring of the tractor. Manual planting of okra at distance, 1 m × 0.8 m was used. Manual weeding was done 3 weeks after planting and every 2 weeks interval till harvesting. Soil samples were collected before and after planting operation to carry out physio-chemical properties in the laboratory. Data on growth parameters and yield of okra were collected and analysed using IBM SPSS Statistics 21. Among the analysis were, correlation, regression and ANOVA. Results obtained showed negative correlation between growth parameters, okra yield and soil bulk density. While soil porosity had positive correlation with growth parameters and okra yield. okra yield was higher in conventional and conservative tillage than in zero tillage. Finite modelled equation with coefficient of linearity (R^2=0.934) on the yield of okra using different tillage systems was generated during regression analysis, revealing predicted output closely equal to the observed yield. Yield of okra can be predicted during cultivation provided soil physical properties and growth parameters of okra are known. It is recommended that conventional and conservative tillage systems should be practiced for improvement in the production of okra fruits in sandy loam soil.

Keywords: conventional, conservative, zero tillage, modeling, yield, growth parameter, soil properties

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1 Introduction

okra production activities in Nigeria have increased in recent years because of its nutritional values such as protein, carbohydrate, minerals salts, sugar, vitamins aromatics colouring agent, iron and essential oil for increasing man's resistance to disease. okra among other vegetables contain vitamins A and B, rich in minerals and very high in iodine content (Dupriez, 1989; Owolarafe et al., 2007; Dilruba et al., 2009; Ngbede et al., 2014; and Bello et al., 2020). okra fruits can be boiled, fried or cooked (Akintoye et al., 2011). Due to its medicinal quality, okra has been known to be beneficial to people suffering from leucorrhoea, goitre, ulcers, relief from haemorrhoids and general weakness (Demir, 2001). okra contains most of the substances needed by human for survival and existence (Faroof et al., 2010). okra is widely grown all over the world because of its apt adaptation to survive on any kind of soil at any period of the season (FAO, 2009). Vegetable growing is a type of intensive farming that produces great quantity of yield on a small area of land. FAO (2020) recorded that okra production was impressive with FAO-supported farmers recording an average of over 7.4 tonnes per hectare, a 68-percent increase compared with unsupported farmers in Northeastern Nigeria. However, insufficient buyers of freshly harvested fruits, lack of

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storage and processing facilities constraints could be alleviated by providing efficient machines to process fresh fruits produced into more durable finished products (Bello et al., 2020).

Tillage has been an integral component of crop production systems since the beginning of agriculture (Mitchell et al., 2009). Tillage systems have effect on crops growth and yield (Odey and Manuwa, 2016). It is one of the fundamental agro-technical operations in agriculture as recorded by Reicosky and Allmaras (2003), Aikin and Afuakwa (2010), Arman (1997), Ozpinar and Clay (2006), Rashidi and Keshaavarzpour (2009), and Afolayan et al. (2010). It a known fact that passes of tractor wheels during tillage of agricultural soil results in stiffness of the soil capable of affecting both the soil properties and subsequent effects on crop growth and yields (Odey et al., 2014). Odey (2018a) revealed that Effects of soil compaction have eaten deep and are adversely affecting the production of food and fibre throughout the world.

Many authors have examined influence of different tillage systems on the growth and yield of crops. Adekiya et al. (2019) reiterated that tillage appears to be indispensable for sustainable okra production on Alfisol of southwest Nigeria. According to Ozpinar and Isik (2004), different tillage systems which affect soil properties include conventional, conservative, reduced, zero tillage or direct seeding, mulch-tillage, ridge-tillage, stale seedbed, minimum tillage and strip-tillage (Allmaras and Dowdy, 1985; Ruberson and Phatak, 1997; Mitchell et al., 2009). The soil must be in a condition that the roots can have air and as well penetrate through with adequate moisture and nutrient (Mamkagh, 2009). Conventional tillage is when the soil is ploughed and harrowed for more than once before sowing of crops. Conversation tillage refers to any tillage system that maintains at least 30% of the soil surface covered by plant residues after tillage and planting primarily where the objective is to reduce water erosion. While in zero tillage, soil is left undisturbed (Rasmussen, 1999; MWPS, 2000; Owen, 2001; ASAE, 2005; Leonard et al., 2000; Mitchell et al., 2009; and Hedayatipoor and Alamooti, 2020). Currently, there is significant interest and emphasis on a shift to the conservation and no-tillage methods for the purpose of reducing soil compaction, controlling erosion, conserving soil and water, mitigating drought, reducing tillage costs, increasing soil organic matter, boosting crop productivity, and reducing net CO_2 emissions which contribute to global warming (Agbede, 2013; Odey et al., 2014, 2018). The physical and chemical properties of the soil affect growth and yield of okra, these include soil strength, bulk density, porosity, soil structure, texture, soil colloid, soil pH, total Nitrogen available phosphorus, total carbon, cation exchange capacity (CEC) and so on (Magdoff and Van Es, 2000).

Predicting crop yields has broad implications for economics, ecology, and human welfare. The large number of factors that determine crop productivity make modeling crop production at large spatial scales substantially challenging. Forecasting crop production is an even greater challenge, as it requires making inferences on future performance based on past conditions. Manjula and Djodiltachoumy (2017) reiterated that data mining is the process of analyzing data from different perspectives and summarizing it into useful information. Crop yield prediction is an important agricultural problem. Farmers always try to focus on yield as soon as cropping activities commence. In the past, yield prediction was calculated by analyzing farmer's previous experience on a particular crop. Sangeeta (2020) proposed system aimed at predicting or forecasting the crop yield by learning the past data of the farming land; by considering soil conditions, rainfall, temperature, yield and other entities. He concluded that proposed model has got more efficiency than the existing model for finding crop yield. Odey (2018b) developed a regression model for predicting the growth of Maize on soil influenced by tractor traffic. The model showed that in any particular cropping season, the yield of maize, *Ym* can be estimated, provided the number of machinery traffic on the land was known. Nkakini and Davies (2020) developed a mathematical model equation for tolerance of okra plant yield to soil densification. It was revealed that there was an approximately closed agreement between the experimented and modelled values of okra yield in tolerance to soil compaction at varying tractor passes in different subplots. The model established that okra growth rate and yield increased significantly with respect to degenerate traffic passes. Hence, this study is aimed at establishing finite modeling of growth and yield of okra using different tillage systems.

2 Materials and methods

2.1 Experimental site and location

The experiment was carried out during the 2017/2018 cropping seasons at the department of Agronomy Research Farm, Faculty of Agriculture and Forestry, Cross River University of Technology, Obubra Campus, Nigeria. The area is located on longitude 08^{o}20$'$00$''$E and latitude 6^{o}05$'$00$''$N. Obubra Local Government Area, Cross River State has about 500-1070 mm annual rainfall. The soil type is sandy loam and a temperature range of 21℃–30℃ (CRADP, 1992). The site has a slightly sloppy topography and rain forest zone.

2.2 Land preparation

The land area was dominated with the following weeds; elephant grass (Penesitum purpurium), chromolina oduvata and centrosea the method adopted for the removal of these weeds after marking out the plot size needed, was firstly through spraying of a systemic herbicide with the help of a portable knapsack sprayer. After a period of two weeks, the vegetation was cleared.

2.3 Experimental design and layout

The design used for the experiment was randomised complete block design (RCBD). The experiment considered a land area of 1,024 m^2. Three different tillage systems including Conventional (A), Conservative (B) and Zero (C) as treatments and each treatment had three replicates of size 8 m × 8 m, separated from each other by 2m for manoeuvring of the tractor.

2.4 Treatments adopted

2.4.1 Conventional tillage

Conventional tillage (ploughing and harrowing) was done using A Massey Fergusson – MF 435 2WD/4WD tractor of 50 kW and 2,122 kg total weight to plough and harrow the plots before seeding.

2.4.2 Conservative tillage

In conservative tillage 1,120 kg of plant residues were used per hectare (1120 kg ha^{-1}) to make up 30% of the soil surface use for crop planting according to ASAE (2005). Hence 7.168 kg of plant residues were used for each 8 m × 8 m plot sizes accordingly. Thus 7.168 kg of crop residue was weighed and incorporated into already ploughed bed and finally harrowed for seed sowing according to Reddy et al. (1992).

2.4.3 Zero tillage

Zero or no tillage operation involved clearing the vegetation and raking before sowing the seed without disturbing the soil to a great extent (Ruberson and Phatak, 1997). The methods used for each treatment were repeated in their various replicates.

2.5 Planting material and germination

The okra seeds (Agwu Early) were sown at 0.02-0.05 m depth with a rate of 2–3 seeds per hole, then, they were later thinned to two stands. Sowing seeds were soaked for 24 hours before sowing (Omran et al., 1980). And the planting distance used in this experiment was 1m × 0.8 m (inter and intra row). Growth and yield data germination was optimal and was calculated using the formula according to Agba et al. (2011);

$$\text{Germination}(\%) = \frac{\text{number of plant germinated}}{\text{Total number of seeds planted}}\ x\ 100 \quad (1)$$

2.6 Cultural practices

2.6.1 Supply of missing stands and thinning

Supply of seedlings raised in a nursery bed beside the experimental farm was done at the planting points where germination did not occur after 1-2 weeks. This was done in the morning and the seedlings were transplanted with ball of soil attached to the roots according to Khan et al. (1990). Thinning was done manually after germination to maintain the desired plant population and optimum performance of the okra plant.

2.6.2 Weeding

Weeding of the experimental farm was done manually with cutlass 3 weeks after planting, then after every 2 weeks interval till commencement of harvest.

2.6.3 Fertilizer application

Nitrogen, Phosphorus and Potassium (NPK), 12 : 12 :17 was applied after 3 weeks of planting through ring method; using 3.2 kg for each experimental plot.

2.7 Data collection

2.7.1 Collection of soil samples

The initial soil samples were collected before the different tillage operations at random from the area of land (1,024 m^2) at the depth of 0-15 cm, 16-30 cm and 31-45 cm using an undisturbed core. Soil samples were collected during the vegetative and reproductive stages at the same depths, from each treatment, the samples collected were dried, ground and sieve with 2 mm sieve for soil analysis.

2.7.2 Measurement of growth parameters and yield of okra

Data on plant height, width, number of leaves and flowers were collected 2 weeks after planting (WAP) and in every 2 weeks interval. This was done using measuring tape and veneer calliper. The okra pods (matured green pods) were harvested every 5 days interval, by cutting the pods with knife and hands.

2.7.3 Soil bulk density and porosity

The samples were oven dried at a temperature of 100℃ for 24 hours and then bulk density and porosity were determined using the method described by Black and Hartge (1986).

2.8 Analysis

2.8.1 Laboratory analysis

Soil samples collected from the experiment were subjected to laboratory analysis at Soil Science Laboratory, University of Agriculture, Makurdi. Particle size; was determined by the hydrometer method as described by Gee and Bauder (1986). Soil pH was determined in water 1:2 soil: water ratio using pH meter with glass electrode. Exchangeable cations, calcium and magnesium were determined in the extract by EDTA titration and potassium and sodium by the use of flame photometer (Udo et al., 2009). Organic matter was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). Available phosphorus was determined by the Bray-1 method as described by Kuo (1996). Total nitrogen was determined by the micro-Kjeldahl digestion and distillation method as described by Bremmer (1996). Cation exchange capacity was determined by method described by Sumner and Miller (1996).

2.8.2 Statistical analysis

Data for growth and yield of okra in this experiment were analysed using IBM Statistical Package for Social Sciences (SPSS) Statistics Version 21. Correlation, regression and ANOVA analysis were carried out.

3 Results and discussion

3.1 Soil properties of the experimental site

The result of pre-treatment of soil physio-chemical properties of the experimental site in Table 1 indicated that the soil is sandy loam with high sand particles in all the depths - 0 to 15 cm, 16 to 30 cm and 31 to 45 cm, the soil was mildly acidic in the various depths. Soil in the depth of 0 to 15 cm contains a higher amount of organic matter than that of 16 to 30 cm and that of 31 to 45 cm, this confirmed that soil organic matter decreases with depth. The soil total N, available P, cations exchange capacity (CEC), Mg and organic matter where low and this is an indication of the inherent low fertility status of tropical soils as reported by Ojeniyi (2010).

Table 1 Pre-Treatment soil properties of the experimental site at depths of 0 to 15 cm, 16 to 30 cm and 31 to 45 cm

Depths	Particle size distribution				pH		Org C%	Org M%	N%	Bray 1 P ppm	Ca cent m	Mg Mol	K kg	Na soil	CEC
	% sand	% silt	% clay	Textural class	H_2O 1:1	KCl 1:1									
0-15cm	76.0	12.0	12.0	Sandy loam	5.93	5.11	0.86	1.49	0.092	3.68	3.71	1.58	0.33	0.64	6.50
16-30cm	75.9	12.9	11.2	Sandy loam	5.91	5.02	0.77	1.33	0.094	3.81	3.69	1.62	0.34	0.70	6.46
31-45cm	70.2	13.7	16.3	Sandy loam	5.50	4.80	0.66	1.14	0.088	3.9	3.77	1.66	0.30	0.69	6.43
SD	± 3.3	± 0.9	± 2.7		± 0.24	± 0.16	±0.10	±0.18	±0.0	±0.11	±0.04	±0.04	±0.02	±0.03	±0.04

Source: Field Data 2017/2018 cropping seasons

3.2 Soil properties as influence by treatments, growth parameters and yield of okra

Tables 2 and 3 showed soil physical properties as influenced by treatments, growth parameters and yield of okra respectively. In Table 2, the result of post-tillage soil physio-chemical properties as influenced by the different tillage systems indicated that soil in all the treatments have the same textural class which is sandy loam soil with sand having higher percentages in the various treatments. Soil pH in all the treatments and their various depths, remains mildly acidic, organic matter was discovered to be higher in the depth 0-15 in both conventional and conservative tillage than the other depths with an exception in zero tillage.

Whereas the different tillage did not increase soil N, available P, Cation exchange capacity (CEC), Mg, Ca and Na in the depth 0 to 15, 16 to 30 cm and 31 to 45 cm. This finding agreed with that of (Brady and Weil., 2002), which reported that soil comprises of minerals, organic matter, water and air. And also agreed with that of (Carter, 2002), which stated that soil texture is the proportion of sand silt and clay.

The results from Table 3 revealed that conventional and conservative tillage influenced or lead to higher fruit production of okra than zero tillage. The results agreed with that of Lal (1991) who stated that different tillage systems can influence okra production in terms of fruits yield.

Table 2 Soil properties as influence by treatments

Treatments	Depths	Particle size distribution				pH		Org C%	Org M%	N%	Bray P1 PPM	Ca vaut cent m	Mg/ mmol	K (%)	Na (%)	CEC
		% sand	% silt	% clay	Textural class	H_2O 1:1	KCl 1:1									
A	0-15cm	71.1	13.1	15.8	Sandy loam	6.17	5.35	0.77	1.33	0.079	3.62	3.58	1.63	0.29	0.68	6.11
	16-30cm	75.4	11.2	13.4	Sandy loam	6.25	5.15	0.74	1.30	0.078	3.46	3.49	1.61	0.29	0.65	6.18
	31-45cm	76.2	11.5	12.3	Sandy loam	6.00	5.20	0.71	1.24	0.077	3.11	3.44	1.58	0.29	0.66	6.00
SD		±3.2	±0.85	±2.7		±0.1	±0.1	±0.03	±0.05	±0.0	±0.26	±0.07	±0.03	±0.0	±0.02	±0.09
B	0-15cm	72.2	13.4	15.4	Sandy loam	5.95	5.00	0.80	1.38	0.077	2.86	3.63	1.57	0.30	0.67	6.20
	16-30cm	76.3	12.4	11.3	Sandy loam	5.86	5.00	0.77	1.33	0.077	3.01	3.58	1.62	0.27	0.64	6.08
	31-45cm	69.2	14.2	16.6	Sandy loam	5.00	4.50	0.56	0.97	0.075	3.05	3.80	1.70	0.31	0.70	6.75
SD		±3.6	±0.9	±2.8		±0.5	±0.3	±0.1	±0.2	±0.0	±0.1	±0.1	±0.1	±0.0	±0.03	±0.4
C	0-15cm	75.4	11.6	13.0	Sandy loam	5.92	5.10	0.72	1.24	0.081	3.77	3.41	1.57	0.26	0.64	5.96
	16-30cm	77.0	12.1	10.9	Sandy loam	6.11	5.90	0.80	1.38	0.079	3.83	3.51	1.60	0.26	0.66	6.21
	31-45cm	75.0	11.3	13.7	Sandy loam	6.25	5.33	0.88	1.52	0.075	3.82	3.50	1.62	0.27	0.67	6.22
SD		±1.06	±0.4	±1.5		±0.2	±0.4	±0.1	±0.1	±0.0	±0.03	±0.1	±0.03	±0.01	±0.02	±0.2

Source: Field Data 2017/2018 cropping seasons

Table 3 Mean values of bulk density, porosity, growth parameters and yield of okra

Treatments/ Replicates	Soil Bulk Density (%)	Soil Porosity	Height of okra (cm)	width of okra(cm)	No of leaves/ stand	No. of flowers/ stand	No. of fruits/ stand	Total yield (kg plot- 64 m^{-2})	Total yield (kg ha^{-1})
A1	0.49	0.82	77	19.78	43.2	17.6	13.6	45.6	7,125
A2	0.52	0.80	75.8	17.76	44	6.4	8	40.8	6,375
A3	0.54	0.80	80.6	23.84	48	4	9.6	48.8	7,625
B1	0.46	0.83	88.6	19.12	56.8	16	16.8	62.4	9,750
B2	0.54	0.79	56.6	13.02	45.6	14.4	7.2	29.6	4,625
B3	0.46	0.83	81.4	25.08	68.8	19.2	19.2	47.2	7,375
C1	0.54	0.80	58	14.24	33.6	9.6	15.2	31.2	4,875

C2	0.59	0.78	75	16.54	44	8.8	8.0	36.8	5,750
C3	0.52	0.80	68.4	14.08	32.8	8.0	5.6	40.8	6,375
SD	±0.04	±0.02	±10.68	±4.26	±11.09	±5.37	±4.83	±10.00	±1562.2

Source: Field Data 2017/2018 cropping seasons

3.3 Correlation of soil properties, growth parameters and yield of okra

The result in Table 4 showed the correlation coefficients for soil properties, growth parameters and yield of okra. It showed that the correlation between height and width of okra tends to one, and almost similar to that of leaves and width which proved that there is a strong positive relationship between height, width and leaves of okra. This result is similar to that of Ariyo et al. (1987) which revealed that there is a strong relationship between the growth parameters of crops. Whereas, the correlation of soil bulk density and porosity to growth parameters and yield of okra revealed that, there was a strong positive correlation between growth parameters and yield of okra and soil porosity. When soil porosity was 1.000, height, width, number of leaves, flowers and yield of okra stood at 0.5249, 0.4904, 0.6115, 0.6825 and 0.6909 respectively. While there was a strong negative correlation between soil bulk density, growth parameters and yield of okra as shown in the Table 4. At soil bulk density of 1.000, soil porosity was -1.000, while height, number of leaves, flowers, and yield of okra were -0.5249, -0.4904, -0.6115, -0.6825 and -0.6909 respectively.

Table 4 Correlation coefficients for soil properties, growth parameters and yield of okra

	Bulk Density	Porosity	Height	Width	Leaves	Flowers	Total Yield
Bulk Density	1.000						
Porosity	-1.000	1.000					
Height	-0.5249	0.5249	1.000				
Width	-0.4904	0.4904	0.7707	1.000			
Leaves	-0.6115	0.6115	0.6399	0.7520	1.000		
Flower	-0.6825	0.6825	0.1731	0.2086	0.5799	1.000	
Total Yield	-0.6909	0.6909	0.9162	0.6459	0.5731	0.2596	1.000

3.4 Regression of soil properties, growth parameters with yield of okra

Regression analysis was done on soil properties such as bulk density and porosity, growth parameters and yield of okra, with yield of okra as the dependent variable. Tables 5 and 6 showed the summary of the results. Regression equation (model) for yield of okra per hectare was generated from the analysis as recorded in the Tables. Thus, a finite model for the yield of okra during different tillage systems was deduced from Table 5.

$$Y_o = -84.64 + 12.23Bd + 93.96P + 0.21H - 0.24NL + 0.20T \quad (2)$$

Where,

Y_o=yield of okra

Bd=soil bulk density

P=soil porosity

H=okra plant height

NL = numbers of leaves of okra

T = experimental treatment

The above modelled Equation 2 had a coefficient of linearity (R^2) of 0.934 as shown in Table 6. Differences between the means of predicted and experimented okra yield at 0.05 level of significance were used to interpret and determine the significance by applying statistical tools. The result of the t-test showed that, there is no significant difference at (p>0.05) between experimented and predicted yield of okra estimated from different tillage systems. This showed that the predicted output model is closely equal to the observed (actual) yield of okra. Hence the output of okra can be predicted in advance for any given agricultural field given other input parameters. These results agreed with the findings of Mulumba and Lal (2008), that say tillage is management inputs that affect soil physical characteristics, which in turn affect the growth and yield of crops.

Table 5 Regression coefficients

Parameters	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for Beta	
	Beta	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-84.64	124.391		-0.680	0.545	-480.511	311.222
Bulk density	12.229	47.091	0.206	0.260	0.812	-137.635	162.092
Porosity	93.963	124.816	0.623	0.753	0.506	-303.257	491.184
Height	0.212	0.050	0.906	4.264	0.024	0.054	0.370
No leaves	-0.244	0.215	-0.271	-1.137	0.338	-0.928	0.440
Treatment	0.201	0.483	0.070	0.416	0.705	-1.337	1.739

Note: Dependent Variable: Yield of okra

Table 6 Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.966[a]	0.934	0.823	1.05255	1.165

Note: a. Predictors: (Constant), Trment, No. leaves, Bulk density, Height, Porosity

b. Dependent Variable: Yield of okra

4 Conclusions

Field experiment conducted was aimed to model the okra growth and yield using different tillage systems. Data were collected and analysed. Results obtained showed a negative correlation between growth parameters, okra yield and soil bulk density. While soil porosity had a positive correlation with growth parameters and okra yield. okra yield was higher in conventional and conservative tillage than in zero tillage. Finite modelled equation with coefficient of linearity, (R^2) of 0.934 on the yield of okra using different tillage systems was generated from the regression analysis, revealing predicted output closely equal to the observed yield of okra. The yield of okra can be predicted during cultivation provided soil physical properties and growth parameters of okra are known. It is recommended that conventional and conservative tillage systems should be practiced for improvement in the production of okra fruits in sandy loam soil.

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