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RESEARCH ARTICLE

Soil Properties, Okra Performance and Nutrient Compositions as Affected by Tillage and Maize Cob Ash

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Abstract

Alfisols, the dominant soil order in southwest Nigeria in which crops are grown possess unfavorable peculiarities such as low inherent fertility and acidity. These limitations can be ameliorated by tillage and organic manuring. Therefore, field experiments were conducted during the 2014 and 2015 cropping seasons to assess the effects of tillage methods and maize cob ash (MCA) on soil properties, yield, growth, mineral, and vitamin C contents of okra fruit. The experiment consisted of 3 × 3 factorial combinations of three tillage methods {zero – tillage ZT, manual ridging MR, and plowing plus harrowing P+H} and three rates (0.0, 3.0, and 6.0 t ha^{-1}) of application of MCA. Tillage methods and MCA influenced soil physical and chemical properties, performance, mineral and vitamin C contents of okra fruit significantly. MCA increased soil K, Ca, Mg, okra yield, growth, mineral and vitamin C contents of okra fruits up to 3 t ha^{-1} level after which there was a decrease. The order of reducing bulk density and soil chemical properties, increasing porosity, yield, growth, mineral and vitamin C contents of okra was: ZT > MR > P+H. Tillage appears to be indispensable for sustainable okra production on Alfisol of southwest Nigeria. Growth and yield of okra in this study was dependent on soil physical properties and chemical properties such as pH, OM, N, and K. Combination of P+H and 3 t ha^{-1} MCA produced better yield, growth, mineral and vitamin C contents of okra compared with other combinations of tillage with MCA. Addition of MCA to either P+H or MR is important to reduce the limitation of acidity associated with tropical Alfisol.

Key words : Tillage, maize cob ash, Alfisol, okra, vitamin C, bulk density, porosity

Introduction

Okra (*Abelmoschus esculentus*. L. Moench) is an important fruit vegetable crop grown worldwide. Okra is one of the most widely known and utilized species of the family Malvaceae (Naveed et al. 2009). Okra is a multipurpose crop due to its various uses of the fresh leaves, bud, flowers, pods, stems, and seeds (Minhretu et al. 2014). Okra immature fruits, which are consumed as vegetables can be used in salads, soups, and stews, fresh or dried, fried or boiled (Ndunduru and Rajabu 2004). According to Chrito and Onuh (2005), okra fruit contains 86% water, 2.2% protein, 10% carbohydrate, 0.2% fat, and vitamins A, B, and C. Okra seeds are a source of oil and protein. The seeds have been used on a small scale for oil production (Gemede et al. 2014). It can also be used as non-caffeinated substitute for coffee. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee (Calisir and Yildizi 2005).

Despite the numerous potentials of okra fruit production, it level of production and yield per hectare has been very low in Nigeria (about 2.7 M t ha^{-1}) compared with India (10.5 M t ha^{-1}), Sudan (10.2 M t ha^{-1}), Egypt (15.7 M t ha^{-1}), and Saudi Arabia (11.5 M t ha^{-1}) according to Varmudy (2011). Among the many factors responsible for low yield is the low fertility status of most soils in the growing areas.

Tillage and the use of organic manures are important agronomic practices that can sustain soil fertility and high crop yield (Adekiya, et al. 2016). Tillage operations are known to influence both the release and conservation of nutrients. Tillage practices modify the soil structure by chang-

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ing physical properties such as soil bulk density, soil porosity, and moisture contents. However, intensive or repetitive tillage causes rapid degradation of soil physical, chemical, and biological qualities especially in the case of Alfisol of southwest Nigeria (Adekiya et al. 2011).

Currently, there is significant interest and emphasis on a shift to the conservation and no-tillage methods for the purpose of 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). However, for large-scale production of crops, especially okra, the use of mechanized tillage that involved plowing and harrowing is inevitable. There had been no study to compared no-tillage and traditional farmers' manual ridging with mechanized tillage for okra production. Therefore, in this study, there is the need to examine the potential of growing okra using zero-tillage, manual ridging, compared with mechanized plowing and harrowing and their effects on soil fertility and okra performance.

Maize cob ash is the ash gotten from the incineration of maize cob, especially after the grains of maize have been eaten, or otherwise utilized. Studies have established ash as a fertilizing and liming material (Abdulhamid and Mustapha 2009; Adekiya et al. 2018; Ewulo 2009; Owolabi et al. 2003). However, the effect of maize cob ash and tillage on soil properties and okra performance has not received research attention. In southwest Nigeria, the dominant soil order on which crops are grown are the Alfisol which possess unfavorable peculiarities such as low fertility, soil acidity, and physical limitations such as crust formation, compaction, shallow and effective rooting depth (Lal 1986). According to the FAO (1994), these limitations can be rectified by tillage and organic manuring. Therefore, a soil management involving an appropriate tillage method and agro waste like maize cob ash will be affordable, adoptable, and environmentally friendly and sustainable and is expected to enhance and sustain high soil fertility, productivity, and okra yield. Moreover, tillage and organic manuring especially ash may also influence the mineral and vitamin C composition of crops. This aspect needs to be investigated for okra. Therefore the objective of this study was determined the effect of tillage methods and maize cob ash on soil properties, yield, growth, mineral and vitamin C contents of okra fruit.

Materials and Methods

Site description and treatments

Field experiments were conducted during the 2014 and 2015 cropping seasons at Owo (latitude 7°12′N, longitude 5°32′E) in the forest–savanna transition zone of southwest Nigeria. The soil at Owo is an Alfisol classified as an Oxic Tropuldalf (USDA 2010) or Luvisol (FAO 1998) derived from quartzite, gneiss, and schist. The top of the soil at the site was sandy loam. There are two rainy seasons, one from March to July and the other from mid-August to November, with temperatures ranging from 24 to 32°C. The average rainfall varied from 1240 to 1346 mm. The experimental site had been under bush fallow for 2 years after arable cropping to maize, yam, and cassava. The predominant weeds at the site were Siam weed (*Chromolaena odorata* L. King and Robinson), water leaf (*Talinum triangulare* Jacq. Wild) and Guinea grass (*Panicum maximum* Jacq.). The experiments were conducted to assess the effects of tillage methods and maize cob ash on soil properties, growth, yield, mineral and vitamin C contents of okra fruit.

The experiment each year consisted of 3 × 3 factorial combinations of three tillage methods {zero – tillage ZT (manual clearing with a cutlass followed by treatment with paraquat - 1,1-dimethyl 4-4-bipyridilium dichloride - at the rate of 2.5 kg ha^{-1} a.i. sprayed 2 weeks before sowing okra seeds on the flat with cutlass in the killed sod without primary or secondary tillage operations), manual ridging MR (the ridge was prepared by heaping the soil surface layer using the traditional hoe after cleared weeds had been removed from the plots) and plowing plus harrowing P+H (soil was plowed and harrowed to 0.20 m depth once using a tractor-mounted disc plow and harrow)} and three rates (0.0, 3.0 and 6.0 t ha^{-1}) of application of maize cob ash (MCA).

The tractor used was a Steyer 768 and its weight was 4500 kg. There was an initial clearing of the plots before tillage operations for treatments P+H. The experiment was laid out in a randomized complete block design with three replications. Each plot size was 12 × 10 m. To minimize interference, blocks were 4 m apart, and plots were 3 m apart. The same tillage treatment and maize cob ash rate was allotted to each plot for the 2 years of study.

Crop establishment

Tillage treatments were carried out in April in both 2014 and 2015. Sowing of okra seeds (variety NHAe-47-4) was done immediately after tillage. Three seeds of okra were sown per hole at inter-row spacing of 0.6 and 0.6 m intra-row and two weeks after sowing, thinning to one plant per stand was done giving a plant population of 27,778 plants ha^{-1} and this was followed by manual weeding using hand hoe before application of maize cob ash. MCA used for the experiment was prepared by collecting maize cob from maize farmers, sundried, and burnt into ashes inside a bin. The ash was then sieved to remove pebbles and unburnt shaft. MCA was applied in ring form to the soil 2 weeks after sowing okra seeds at the rates 0.0, 3.0, and 6.0 t ha^{-1}. Subsequent weeding was done manually during the planting season, and insect pest control was carried out using cypermetrin applied at the rate of 30 ml per 10 l of water.

Soil sampling and analysis

Before the commencement of the experiment in 2014, soil samples were taken from 0–0.15 m depth at 10 points selected randomly from the experimental site. Soil samples were collected using steel coring tubes (0.04 m diameter, 0.10 m high) and were put in an oven set at 100°C for 24 h for the determination of bulk density. The soil samples collected were also bulked, air-dried, and sieved using a 2 mm sieve and analyzed for particle size, soil organic matter, N, P, K, Ca, Mg, and pH. Soil samples were also collected at harvest of okra from 0–0.15 m depth in 2014 and 2015 on an individual plot basis and similarly analyzed for chemical properties. Samples were analyzed as described by Carter (1993). Particle size was analyzed by the hydrometer method (Sheldrick and HangWang 1993). Soil organic carbon was determined by the procedure of Walkley and Black using the dichromate wet oxidation method (Nelson and Sommers 1996). Organic matter was calculated by multiplying C by 1.724. Total N was determined by the micro-Kjeldahl digestion method (Bremner 1996). Available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry (Frank et al. 1998). Exchangeable K, Ca, and Mg were extracted using 1M ammonium acetate. Thereafter, K level was determined on a flame photometer, and Ca and Mg were determined by EDTA titration (Hendershot et al. 2007). Soil pH was determined using a soil-water medium at a ratio of 1:2 with a digital electronic pH meter.

One month after sowing of okra seeds, determination of certain soil physical properties in all plots commenced and this was done at two-week intervals on four occasions for each year. Six samples (0.04 m diameter, 0.10 m high) were collected at 0.10 m depth from each plot using a steel core sampler and were used for the evaluation of bulk density, total porosity, and gravimetric water content after oven-dried at 100°C for 24 h. Total porosity was calculated from the values of bulk density and particle density.

Growth and yield observations

Growth parameters measured were plant height (by the use of meter rule) and leaf area - at mid-flowering was determined by using the model $\{LA=0.34(LW)^{1.12}\}$ developed by Omolaiye et al. (2015), where LA = leaf area, L= leaf length and W = leaf width. Pods were harvested at 4-day intervals counted and weighed. Pod weight was evaluated based on the cumulative number of pods at eight harvests.

Analysis of maize cob ash and okra fruits

About 2 g of the ash used was collected and analysed for N, P, K, Ca, and Mg as described by Tel and Hagarty (1984). N was determined by the micro-Kjeldahl digestion method. Samples were digested with nitricperchloric- sulphuric acid mixture for the determination of P, K, Ca, and Mg. Phosphorus was determined colorimetrically using the vanadomolybdate method, K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method (Horwitz and Latimer 2005).

Each year, 10 okra fruits of uniform sizes were randomly collected from each plot and analyzed for mineral contents. Mineral elements of okra fruits were determined according to methods recommended by the Association of Official Analytical Chemists (AOAC 2003). One gram of each sample was digested using 12 cm^{-3} of the mix of HNO_3, H_2SO_4, and $HClO_4$ (7:2:1 v/v/v). Contents of Cu, Fe, K, and Ca were determined by atomic absorption spectrophotometry and vitamin C content was determined by using the indophenol dye method (Singh et al. 2007).

Statistical analysis

Data collected from each experiment were subjected to analysis of variance (ANOVA) using the Genstat statistical package (GENSTAT 2005) to determine the effects of treatments on soil physical and chemical properties, growth, yield, mineral and vitamin C contents of okra fruit. The standard error of difference between means (s.e.d.) was used to compare the treatment means. Mention of statistical significance refers to $P = 0.05$ unless otherwise stated.

Results

Table 1 shows the results of the physical and chemical properties of the experimental site and the chemical analysis of the MCA used for the experiment. The soil was sandy loam in texture, high in bulk density, acidic and low in organic matter (OM), total N, exchangeable K and Ca and adequate in available P and exchangeable Mg according to the critical levels of 3.0% OM, 0.2% total N, 10.0 mg kg^{-1} available P, 0.16-0.20 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca, and 0.40 cmol kg^{-1} exchangeable Mg recommended for crop production in ecological zone of Nigeria (Akinrinde and Obigbesan 2000). Analysis of MCA showed that the pH was very strongly alkaline and it also contained high level of K, Ca, Mg, and trace values of N and P.

Changes in soil properties

The effect of soil physical properties on year, tillage

Table 1. Soil properties before experimentation and nutrient contents of maize cob ash used for the study.

Property	Soil values	Maize cob ash values
Sand (%)	69	nd
Silt (%)	17	nd
Clay (%)	14	nd
Textural class	Sandy loam	nd
Bulk density (Mg m^{-3})	1.46	nd
pH (water)	5.56	11.1
Organic matter (%)	2.81	nd
Total N (%)	0.19	0.16
Available P (mg kg^{-1})	11.1	0.24
Exchangeable K (cmol kg^{-1})	0.15	5.9
Exchangeable Ca (cmol kg^{-1})	1.81	1.8
Exchangeable Mg (cmol kg^{-1})	0.40	3.8

nd = not determined

methods, and MCA levels is shown in Table 2. When studied as an individual factor, Tillage methods (T) and MCA levels influenced soil physical properties (bulk, porosity, and moisture content) significantly. Effect of year (Y) on soil physical properties was not significant. Plowing plus harrowing (P+H) had lower bulk density, higher porosity, and lower moisture content compared with zero tillage (ZT) and manual ridging (MR). The order of reducing bulk density and moisture content and increasing porosity was ZT > MR > P+H. Maize cob ash reduced bulk density and increased porosity and moisture content from 0-6 t ha^{-1} in both years. In 2014, compared with the initial status of the soil before experimentation, application of 6 t ha^{-1} MCA reduced the bulk density of ZT, MR, and P+H soil by 6.8, 13, and 19.2% respectively. In 2015, the reduction was by 11.0, 17.1, and 24%, respectively. The interactive effect of Y × T, Y × MCA and Y × T × MCA were not significant. However, T × MCA was significant.

Data containing the effect of soil chemical properties on year tillage methods and MCA levels are shown in Table 3. Year, tillage methods and MCA influenced soil chemical properties significantly, however, year (Y) did not influence pH, OM, N, and P significantly. The order of soil chemical properties among tillage methods was P+H < MR < ZT. The values of pH and OM were not significant for tillage methods. Maize cob ash increased all soil chemical properties (pH, P, K, Ca, and Mg) considered significantly except N and OM. The increase in soil pH and OM using MCA was from 0-6 t ha^{-1} while the increase was only up to 3 t ha^{-1} MCA for K, Ca and Mg. Although, 3 t ha^{-1} ash had the highest values of N in both years, there were no significant differences between 0, 3 and 6 t ha^{-1} MCA. The interactive effect of Y × T and Y × T × MCA were not significant. That of Y × MCA was only significant for K, Ca, and Mg and not for pH, OM, N and P. Also T × MCA was significant only for N, P, K, Ca, Mg, and pH and not for OM.

Response on okra yield

Data containing the effect of okra yield and growth on year, tillage methods, and MCA levels are shown in Table 4. When studied as individual factors, tillage method (T) and MCA influenced yield and growth of okra significantly. Year (Y) did not have influence on okra yield and growth

Table 2. Effect of year, tillage methods, and maize cob ash on soil physical properties.

Year	Tillage method	Maize cob ash level (t ha^{-1})	Bulk density (Mg m^{-3})	Total porosity (%)	Moisture content (%)
2014	ZT	0.0	1.46	44.9	16.2
		3.0	1.40	47.2	17.8
		6.0	1.36	48.7	19.5
	MR	0.0	1.37	48.3	13.4
		3.0	1.30	50.9	15.3
		6.0	1.27	52.1	17.1
	P+H	0.0	1.26	52.5	12.1
		3.0	1.21	54.3	13.6
		6.0	1.18	55.5	15.3
2015	ZT	0.0	1.54	41.9	14.4
		3.0	1.34	49.4	18.7
		6.0	1.30	50.9	20.6
	MR	0.0	1.42	46.4	11.6
		3.0	1.25	52.8	16.8
		6.0	1.21	54.3	18.6
	P+H	0.0	1.34	49.4	10.3
		3.0	1.15	56.6	14.9
		6.0	1.11	58.1	16.8
Year (Y)			ns	ns	ns
Tillage (T)			*	*	*
Maize cob ash (MCA)			*	*	*
Y × T			ns	ns	ns
Y × MCA			ns	ns	ns
T × MCA			*	*	*
Y × T × MCA			ns	ns	ns

Note: *Significant difference at P = 0.05; ns, not significant at 0.05. ZT, zero tillage; MR, manual ridging; P + H, plowing plus harrowing.

Table 3. Effect of year, tillage methods, and maize cob ash on soil chemical properties.

Year	Tillage method	Maize cob ash level (t ha^{-1})	pH (water)	Organic matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})	Exchangeable Ca (cmol kg^{-1})	Exchangeable Mg (cmol kg^{-1})
2014	ZT	0.0	5.51	2.76	0.18	10.2	0.14	1.7	0.37
		3.0	6.89	2.90	0.19	12.5	0.38	2.9	0.42
		6.0	6.95	3.10	0.19	13.7	0.34	2.5	0.41
	MR	0.0	5.48	2.46	0.16	9.8	0.13	1.5	0.34
		3.0	6.84	2.61	0.17	10.6	0.28	2.5	0.40
		6.0	6.91	2.79	0.17	12.1	0.24	2.5	0.40
	P+H	0.0	5.40	2.23	0.16	8.9	0.11	1.3	0.30
		3.0	6.82	2.46	0.17	9.5	0.20	2.2	0.36
		6.0	6.91	2.66	0.17	10.7	0.19	2.2	0.35
2015	ZT	0.0	5.49	2.71	0.17	10.1	0.14	1.5	0.35
		3.0	7.10	2.96	0.18	13.8	0.40	3.6	0.48
		6.0	7.40	3.20	0.18	14.7	0.40	3.5	0.47
	MR	0.0	5.40	2.34	0.16	9.7	0.12	1.4	0.32
		3.0	7.05	2.78	0.16	11.9	0.30	3.1	0.40
		6.0	7.15	2.89	0.17	12.4	0.30	3.0	0.38
	P+H	0.0	5.38	2.18	0.16	8.4	0.09	1.2	0.28
		3.0	6.91	2.65	0.17	10.2	0.26	2.8	0.38
		6.0	7.01	2.77	0.17	12.3	0.21	2.7	0.37
Year (Y)			ns	ns	ns	ns	*	*	*
Tillage (T)			ns	ns	*	*	*	*	*
Maize cob ash (MCA)			*	ns	ns	*	*	*	*
Y × T			ns	ns	ns	ns	ns	ns	ns
Y × MCA			ns	ns	ns	ns	ns	*	*
T × MCA			*	ns	*	*	*	*	*
Y × T × MCA			ns	ns	ns	ns	ns	ns	ns

Note: *Significant difference at $P = 0.05$; ns, not significant at 0.05. ZT, zero tillage; MR, manual ridging; P + H, plowing plus harrowing.

Table 4. Effect of year, tillage methods, and maize cob ash on yield and growth of okra.

Year	Tillage method	Maize cob ash level (t ha^{-1})	Fruit yield (t ha^{-1})	Plant height (m)	Leaf area/plant (m^2)
2014	ZT	0.0	6.9	0.39	0.66
		3.0	7.6	0.45	0.71
		6.0	7.4	0.44	0.69
	MR	0.0	7.9	0.43	0.75
		3.0	8.6	0.49	0.79
		6.0	8.5	0.46	0.76
	P+H	0.0	8.8	0.51	0.84
		3.0	9.9	0.55	0.89
		6.0	9.6	0.51	0.81
2015	ZT	0.0	6.5	0.33	0.61
		3.0	7.9	0.54	0.78
		6.0	7.6	0.52	0.76
	MR	0.0	7.1	0.39	0.69
		3.0	8.9	0.59	0.86
		6.0	8.7	0.55	0.80
	P+H	0.0	8.2	0.46	0.77
		3.0	10.6	0.67	0.96
		6.0	9.8	0.65	0.94
Year (Y)			ns	ns	ns
Tillage (T)			*	*	*
Maize cob ash (MCA)			*	*	*
Y × T			ns	ns	ns
Y × MCA			ns	ns	ns
T × MCA			*	*	*
Y × T × MCA			ns	ns	ns

Note: *Significant difference at $P = 0.05$; ns, not significant at 0.05. ZT, zero tillage; MR, manual ridging; P + H, plowing plus harrowing.

Table 5. Effect of year, tillage methods, and maize cob ash on mineral and vitamin C compositions of okra fruits.

Year	Tillage method	Maize cob ash level (t ha^{-1})	K (%)	Ca (%)	Mg (%)	Cu (%)	Fe (%)	Vitamin C (mg 100^{-1} g)
2014	ZT	0.0	112.1	144.8	135.4	0.61	14.1	11.6
		3.0	144.7	178.4	163.6	0.69	15.9	13.8
		6.0	143.6	174.3	161.8	0.64	15.4	13.7
	MR	0.0	134.6	156.1	148.6	0.68	16.6	12.8
		3.0	154.1	189.1	177.1	0.75	17.8	14.9
		6.0	150.4	180.0	177.0	0.71	17.5	14.6
	P+H	0.0	146.0	171.8	168.3	0.79	18.8	13.6
		3.0	178.3	195.1	186.8	0.88	20.1	17.5
		6.0	168.4	194.3	184.1	0.88	20.1	17.3
2015	ZT	0.0	107.3	127.1	121.8	0.55	13.0	10.1
		3.0	157.4	189.6	172.4	0.78	16.5	14.8
		6.0	150.8	187.1	170.3	0.77	16.4	14.5
	MR	0.0	119.6	138.2	130.1	0.65	14.6	11.1
		3.0	174.3	205.7	188.4	0.85	18.4	17.5
		6.0	170.2	201.5	184.1	0.84	18.2	17.2
	P+H	0.0	131.5	161.4	158.6	0.71	17.1	12.5
		3.0	190.4	250.7	279.6	0.98	23.4	18.8
		6.0	185.6	245.2	270.3	0.96	23.1	18.1
Year (Y)			*	*	*	*	ns	ns
Tillage (T)			*	*	*	*	*	*
Maize cob ash (MCA)			*	*	*	*	*	*
Y × T			ns	ns	ns	ns	ns	ns
Y × MCA			*	*	*	*	ns	ns
T × MCA			*	*	*	*	*	*
Y × T × MCA			ns	ns	ns	ns	ns	ns

Note: *Significant difference at $P = 0.05$; ns, not significant at 0.05. ZT, zero tillage; MR, manual ridging; P + H, plowing plus harrowing.

significantly. Tillage influenced the yield and growth of okra in increasing order: ZT < MR < P+H. Maize cob ash in both years influenced okra yield and growth up to 3 t ha^{-1} level after which there was a decrease at 6 t ha^{-1} level. The optimum yield and growth was attained with P+H at 3 t ha^{-1} MCA. Compared with the control, application of MCA at 3 t ha^{-1} increased fruit yield of okra for ZT, MR, and P+H soils by 7.2, 8.9 and 12.5 in 2014 and 21.5, 25.4, and 29.3, respectively, in 2015. The interactive effect of Y × T, Y × MCA, and Y × T ×MC A were not significant. T × MCA was significant.

Response on okra quality

Data on the effect of okra fruit mineral and vitamin C contents on year, tillage methods, and MCA levels are presented in Table 5. As individual factor year (Y), tillage methods (T), and MCA influenced okra mineral and vitamin C contents significantly. Y did not influence Fe and vitamin C significantly. Year 2015 had higher values of K, Ca, Mg, and Cu compared with year 2014. Among tillage methods, P+H had the highest values of K, Ca, Mg, Cu Fe, and Vitamin C. the optimum values of K, Ca, Mg, Cu Fe, and Vitamin C was attained at MCA applied at 3 t ha^{-1} in both years. The interactive effect of Y × T and Y × T × MCA were not significant. Y × MCA and T × MCA were significant. Y × MCA was not significant for Fe and vitamin C.

Discussion

Results (Table 1) show that the site was low in OM, N, K, Ca, acidic with high bulk density. These conditions are the characteristics of Alfisols of southwest Nigeria (deRidder and Vankeulen 1990; Lal 1986). The fairly high bulk density before the start of the experiment was attributed to the low organic matter of the site (Obi and Nnabude 1995). The lower bulk density of P+H and MR compared with ZT was due to the loosening effects of tillage. The low bulk density of P+H compared with MR could be attributed to better pulverization of the soil by plowing and harrowing. The high bulk density of ZT compared with MR and P+H could be due to non-tillage or compaction (Adekiya and Ojeniyi 2002; Hulugalle et al. 1985). P+H with less bulk density had higher values of total porosity. This observation confirmed the inverse relationship between bulk density and total porosity. ZT had higher moisture content compared with MR and P+H. This could be related to organic matter in the soil surface which acted as mulch to reduce evaporation loss of water. The higher moisture content of ZT could also be related to their density, attendant lower porosity, and evaporation rate. Ojeniyi (1981) had earlier found that for sandy soils of southwest Nigeria, moisture content increased with bulk density. Hence, ZT soils with high bulk density value recorded relatively high moisture content.

MCA reduced bulk density and increased porosity of the soil. The increase porosity could be related to the porous nature of the ash. MCA reduced bulk density because porosity of ash is high and when applied to soil it significantly decease bulk density by increasing the pore volume. The reduction in bulk density and increased porosity as result of MCA could also be related to increased SOM and Ca. Both substances are cementing and stabilizing agents in soil aggregation. Improved aggregation leads to increase in porosity and reduction in bulk density. Ogbodo and Nnabude (2012) found that ash derived from burnt rice husks ameliorated unfavorable soil physical conditions in rice soil at Abakaliki, southeast Nigeria by reducing soil bulk density, increasing porosity, and infiltration rate. Similarly, Lal et al. (1996), Matte and Kene (1995), Miller (1999), and Dhindsa et al. (2016) also found that fly ash amendment to soils decreased bulk density. The increase in moisture content of the soil as a result of ash application was adduced to the soil having more micropores for physically retaining water. It can also be attributed to increased OM from the MCA which improved aggregation that created pore spaces resulting from greater earthworm burrowing and hence improve moisture. The interaction of T × MCA was significant, signifying the combinations of tillage and MCA in improving soil physical properties. Tillage in combination with MCA reduced soil bulk density, increased porosity, and moisture content. It obliterated effect of high soil bulk density and lower porosity associated with zero tillage.

In both years, soil chemical properties tend to be in the increasing order of P+H < MR < ZT. The higher nutrient contents of ZT compared with other tillage methods could be due to the presence of vegetative surface mulch which reduced leaching and increased activities of beneficial soil fauna in organic matter decomposition (Ojeniyi and Adekayode 1999). The lower values of soil chemical properties due to P+H can be adduced to leaching, increased biological activities, and oxidation. The higher nutrient content of MR compared with P+H could be due to minimal disturbance of soil in MR compared with P+H during land preparation.

The result that MCA increased soil pH, P, K, Ca, and Mg contents can be due to the low initial soil fertility status of the site before experimentation. It also consistent with the analysis recorded for MCA (Table 1) and also the use of ash as soil amendment (Agbede and Adekiya 2012; Ezekiel et al. 2009; Ojeniyi et al. 2002; Owolabi et al. 2005). The increase in pH as a result of MCA is consistent with the fact that MCA being a Ca-containing mineral raised soil pH. This confirmed that MCA improved the base status of the soil to which it is applied. The result that optimum soil chemical properties (N. P, K, Ca, and Mg) was attained at 3 t ha^{-1} MCA can be adduced to the fact that 3 t ha^{-1} MCA was amount required for soil in the study area or similar soils elsewhere to significantly improve soil deficient in N, P, K, Ca, and Mg. The significant effect of K, Ca, and Mg in 2015 compared with 2014 was due to the residual effect of the ash in the second year due to accumulation from the first year.

In both years, P+H produced the highest values of okra fruit yield, plant height and leaf area compared with MR and ZT. This can be adduced to its lower bulk density and higher porosity. The higher bulk density produced by other tillage methods especially ZT could cause mechanical impedance to root and this would adversely affect nutrient and water uptake, hence reduced yield and growth of okra. From this study, a degree of tillage appears to be indispensable for sustainable okra production on Alfisol of southwest Nigeria.

The addition of MCA to the soil significantly increased the yield and growth of okra. This is because ash is reported to increase soil nutrients (Nweke et al. 2016; Owolabi et al. 2005) and improved soil physical properties (Ogbodo and Nnabude 2012) compared with the control. Reduction of bulk density due to MCA would have increased nutrient and water uptake compared with no application. The result that irrespective of tillage methods, 3 t ha^{-1} MCA produced the optimum yield and growth of okra implies that the amount is just sufficient for okra production. Application of MCA up to 6 t ha^{-1} would be at the luxury level and contribute less to yield. The interactive effect T × MCA was significant for okra yield and growth. This could be due to positive cumulative relationship between tillage and MCA which further enhanced or fortified their improvement in soil physical and chemical properties. Combination of P+H and 3 t ha^{-1} MCA produced better yield and growth of okra compared with other combinations. This can be adduced to reduced bulk density of P+H and optimum soil chemical properties produced by 3 t ha^{-1} MCA.

The result was that okra mineral compositions were significantly increased in 2015 compared with 2014 is consistent with the soil chemical properties of these elements in the soil. It also shows the residual effects of these elements in the second year of application of MCA. The fact that tillage methods influenced mineral and vitamin C contents of okra fruit was due to the physical and chemical properties of the soil. The better performance of P+H compared with other tillage methods in term of mineral composition can be adduced to lower bulk density and high porosity of P+H which gave it better assess to nutrient in the soil compared with other tillage methods. Wozniak (2016) found that triticale grain from conventional tillage plots contains more starch, Mg, Mn, and Fe than grains from reduced tillage and no-tillage systems. The significant influence of MCA on mineral and vitamin C composition of okra indicated that MCA contains some nutrients which are released in the soil upon mineralization. MCA increased soil nutrient such as N, P, K, Ca, Mg, and pH which are essential for improved mineral and vitamin C composition of okra.

The multiple regression of growth and yield component using soil chemical and physical properties (Table 6) shows that growth and yield of okra in this study was dependent on soil physical properties and chemical properties such as pH, OM, N, and K. This finding is as a result of degree of soil pulverization and the ease of root penetration to absorb the mineral in the soil. Trouse (1979) indicated that soil compressed just above 0.15 Mg m^{-3} could reduce root growth to

Table 6. Effect of multiple regressions of growth and yield component using soil chemical and physical properties.

Growth and yield component	R^{2*}	Soil properties	p- value
Yield	0.990	pH, OM, N, P, K, Ca, Mg, BD, Porosity, MC	>0.042, >0.003, >0.006, >0.079, >0.001, >0.007, >0.768, >0.021, >0.025, > 0.000
Plant height	0.990	pH, OM, N, P, K, Ca, Mg, BD, Porosity, MC	>0.049, >0.047, >0.000, >0.133, >0.502, >0.077, >0.981 >0.032, >0.000, >0.000
Leaf area	0.994	pH, OM, N, P, K, Ca, Mg, BD, Porosity, MC	>0.006, >0.047, >0.000, >0.168, >0.016, >0.535, >0.004, >0.035, >0.002, >0.000

*Significant at P = 0.05 level; SOM: soil organic matter; N: total nitrogen; P: available phosphorous; K: exchangeable potassium; Ca: exchangeable calcium; Mg: exchangeable magnesium; BD: bulk density; MC: moisture content;

about half of its capacity, such reductions in root growth could prevent nutrient and mineral absorption. Adekiya et al. (2017) showed that N and K are the most important macronutrient required for growth and okra yield. Furthermore, the high percentage of Ca in MCA (Table 1) should have enabled it to serve as a liming material for the control of acidity considering its high pH. The limitation of the test soil is acidity which is known to reduce uptake and availability of nutrients important to okra (Adekiya et al. 2017; Brady and Weil 1999). It was reported that the optimum pH for okra is 6.5 (Simmone et al. 2004).

Conclusion

Tillage methods and MCA influenced soil physical and chemical properties, yield, growth, and mineral and vitamin C contents of okra fruit significantly. Year did not influence soil physical properties, pH, OM, N, P, yield, and growth of okra significantly, but did influence soil K, Ca, Mg and K, Ca, Mg and Cu contents of okra fruit. Maize cob ash in both years influenced soil K, Ca, Mg, okra yield, growth, mineral and vitamin C contents of okra fruits up to 3 t ha^{-1} level after which there was a decrease at 6 t ha^{-1} level. From this study, a degree of tillage appears to be indispensable for sustainable okra production on Alfisol of southwest Nigeria. Growth and yield of okra in this study was dependent on soil physical properties (bulk density, porosity and moisture content) and chemical properties such as pH, OM, N, and K. Although, combination of P+H and 3 t ha^{-1} MCA produced better yield, growth, mineral and vitamin C contents of okra compared with other combinations of tillage with MCA, addition of MCA to P+H or MR is important to reduce the limitation of acidity associated with tropical Alfisol.

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