



Dry matter yield of okra and Nutrient Dynamics with cocoa pod husk-based compost and NPK fertilizer in an Ultisol

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Abstract

Dry matter yield of okra with cocoa pod husk-based (CPH) compost was assessed in a pot experiment. Three CPH-based composts: CPH+Neem leaf (CPH+NL), CPH+Poultry manure (CPH+PM) and CPH+PM+NL at the rate of 25, 50, 75, 100 kg N ha⁻¹ each and NPK fertilizer at 40, 50, 60 kg N ha⁻¹ and control, were applied to 5 kg soil each with three replicates and arranged in a completely randomized design. Two varieties of okra (NH47-4 and LD88) were grown. Plant height, stem girth and number of leaves were measured at 6 weeks after sowing while dry matter yield (DMY) and nutrient uptake were determined. Pre- and post- cropping soil analyses were done. Data were analyzed using ANOVA and means separated by DMRT at $\alpha = 0.05$. DMY for NH47-4 ranged from 6.5g (control) to 16.7g (NPK 60 kg N ha⁻¹) and from 5.1g (control) to 7.5g (CPH+NL 100 kg N ha⁻¹) while LD88 ranged from 8.3 g (control) to 19.1g (CPH+PM 75 kg N ha⁻¹) and 4.0g (control) to 9.6g (CPH+PM75 kgNha⁻¹) in main and residual planting respectively. The N, P and K uptake of NH47-4 and LD88 were significantly enhanced with fertilizer treatments compared to the control. After the residual planting, pH of soil ranged from 6.2 (control) to 7.0 (CPH+NL 50 kg N ha⁻¹) with NH47-4 and 6.3 (control) to 6.9 (CPH+PM+NL 50 kg N ha⁻¹) with LD88. Organic carbon ranged from 9.7 gkg⁻¹ (control) to 22.7 gkg⁻¹ (CPH+PM+NL 50 kg N ha⁻¹) with NH47-4 and 13.9 gkg⁻¹ (control) to 20.3 gkg⁻¹ (CPH+PM+NL 50 kg N ha⁻¹) with LD88. Total N ranged from 0.1 gkg⁻¹ (control) to 0.8 gkg⁻¹ (CPH+PM+NL 100 kg N ha⁻¹) with NH47-4 and 0.1 gkg⁻¹ (control) to 0.7 gkg⁻¹ (CPH+PM+NL 75 kg N ha⁻¹) with LD88. The P, Ca, Mg and Na were significantly increased with fertilizer compared to control. It could therefore be concluded that CPH-based compost could be a good fertilizer for okra growth and soil fertility improvement.

Keywords: Cocoa pod husk, compost, dry matter yield, okra, Nutrient uptake..

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Article Info

Received : 20.09.2019

Accepted : 13.10.2020

Available online : 28.10.2020

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Introduction

Cocoa pod husk (CPH) is considered a waste and vast quantity is being disposed off daily as a result of ignorance of its efficacy as an organic fertilizer source. Though CPH is being used in the manufacturing of local black soap, majority of the populace is oblivious of its ameliorating effects on nutrient depleted soils. It was estimated that 64,000-94,000 tonnes of nutrients like K, Ca and P and between 6,000-9,000 tonnes of N are lost from CPH annually. Cocoa pod husk is slow releasing relative to inorganic fertilizers (Adeoye et al. 2001) and it increased soil organic matter, soil total N, available P, exchangeable cations (such as K and Ca) compared to inorganic fertilizers (Moyinjesu, 2003).

Okra (*Abelmoschus esculentus*) is an important fruit vegetable cultivated in the tropical regions mainly for its pod (Olaniyi et al., 2010; Akintoye et al. 2011). It is an important vegetable crop throughout the tropics and

doi : <https://doi.org/10.18393/ejss.816577>

http : <http://ejss.fesss.org/10.18393/ejss.816577>

Publisher : Federation of Eurasian Soil Science Societies

e-ISSN : 2147-4249

sub-tropics (Akinyele and Osekita, 2006). The immature pods serve as ingredients of soup and stew (Osekita et al., 2000) and are eaten either fresh or cooked by boiling or frying. Okra is a popular vegetable among both the consumers and farmers because it is rich in vitamins and minerals (Oyelade et al., 2003). Application of compost has been reported to significantly increase growth, dry matter yield and fruit yield of okra (Akanbi et al., 2010). This was attributed to the fact that sufficient supply of nitrogen (N) from the compost will improve cell division and multiplication, foliage production and photosynthetic activity of the plant, thus improving the dry matter accumulation and partitioning into economic part of the plant. Also N is a major component of protein and chlorophyll which will affect both yield and quality of crops. The distribution of biomass between roots and shoots influences the photosynthetic capacity and nutrient uptake of a plant, consequently affecting its relative growth rate (van der Werf, 1996). N is the most important nutrient required for adequate growth and high yield in okra. Unfortunately, N deficiency in plant is widespread in the tropics on account of low soil fertility while the coarse-textured nature of top soils and rainfall patterns favour high nitrate losses through leaching (Xu et al., 2013). The present study therefore was aimed at assessing the effect of soil amendment with cocoa pod husk-based compost and NPK mineral fertilizer on growth dry matter yield and nutrient dynamics of soil of okra.

Material and Methods

Soils (0-15 cm) were collected, bulked, properly mixed to ensure homogeneity, air-dried, sieved and sub-sampled for nutrient analysis and 5 kg soil was weighed into each plastic pot. Three types of compost were prepared using cocoa pod husk (CPH), neem leaves (NL) and poultry manure (PM) in the following ratios by weight.

(i) CPH + NL + PM (3:1:1)

(ii) CPH + PM (3:1)

(iii) CPH + NL (3:1)

The CPH was chopped into smaller pieces before composting to reduce the particle size. The temperature of each pile was monitored daily for the first week and every other day for the next four weeks and weekly until the end of the composting with the use of a soil thermometer. The mixtures were turned and watered every fortnight. The organic materials were composted for three months after which they were allowed to cure for two weeks, shredded and bagged for use

The treatments; 25, 50, 75, 100 kg N ha⁻¹ of each compost and NPK mineral fertilizer at 40, 50, 60 kg N ha⁻¹ and control, were applied to 5 kg soil each and arranged in a completely randomized design in three replicates. Two varieties of okra (NH47-4 and LD88) were used as test crop. There were 32 treatment combinations replicated three times to give 96 experimental units kg N ha⁻¹.

The CPH-based compost was applied two weeks before planting by mixing thoroughly with the soil in each pot after which water was added. Each pot was placed on saucer to collect leachates and poured back to the pot every other day. Three seeds of okra were sown per pot but later thinned to two plants per pot at 2 weeks after sowing. NPK fertilizer was applied one week after sowing. Supplementary watering was maintained throughout the growth period. At six weeks after planting (6 WAS) data were collected on plant height, stem girth and number of leaves after which the plants were harvested by cutting at soil surface in each pot. The roots were carefully removed and washed. Thereafter, roots and shoots were oven-dried at 70°C until constant weight and plant dry matter yields calculated by adding the weight of the shoot and root. The dry matter partitioning was calculated as the ratio of either the root or the shoot to the total plant dry weight. After oven drying, the materials were milled and analyzed for N, P and K concentrations. Nutrient uptake in shoot was calculated using the formula:

$$\text{Nutrient uptake} = \% \text{ nutrient concentration} \times \text{dry matter yield (mg / plant)}$$

Residual effects of compost and inorganic fertilizer on dry matter yield and nutrient uptake of okra were investigated a week after harvesting. The experiment was carried out without further fertilizer applications. The soil in each pot was watered to field capacity and okra varieties (NH47-4 and LD88) were re-seeded. At 6 weeks after sowing, data were collected on plant height, stem girth and number of leaves after which the plants were harvested by cutting at soil surface in each pot. The same procedure in the main planting was repeated. The data were subjected to statistical analysis using one way ANOVA and the means were separated by Duncan's Multiple Range Test (DMRT) at 5 % probability level.

The CPH, NL, and PM were analyzed for total carbon C, N, P, K, Ca, Na and Mg before composting. At maturity, samples were randomly taken from each compost type, milled and subjected to chemical analyses. The pH of the composts were determined in 1:2 sample water ratio using Electrometric method (IITA, 1982). Organic

carbon was determined by dry ashing method (Nelson and Sommers, 1996). Total N was determined by the micro-Kjeldahl method (Bremner, 1996). The samples were digested with perchloric and nitric acids; P was determined by vanadomolybdate yellow color procedure (Olsen and Dean, 1965), K and Na by flame photometer; Ca and Mg by Atomic Absorption Spectrophotometer.

Representative soil samples were taken and used for the following analysis: soil particle size, pH (H₂O), organic C, Total N, available P as well as exchangeable K, Na, Ca and Mg. Particle size analysis was determined using the Bouyoucos hydrometer method (Sheldrick and Wang, 1993). Soil pH was determined in distilled water at a 1:2 (w/v) soil to water ratio using Electrometric method (IITA, 1982). Total N was determined using the micro-Kjedahl digestion method (Bremner, 1996) while organic carbon was determined using dichromate wet oxidation procedure of Walkley and Black (Nelson and Sommers, 1996). Available P was extracted using Bray-P1 method (IITA, 1982) and determined colourimetrically following the procedure of Murphy and Riley (1962). Exchangeable K, Ca, Mg, and Na were extracted with 1N (pH 7.0) ammonium acetate (Hendershot and Lalonde, 1993). Thereafter, the amounts of K and Na in the filtrates were determined using flame photometer, while Ca and Mg were determined using Atomic Absorption Spectrophotometer (AAS). Exchangeable acidity was extracted with 1 N potassium chloride (KCl) (Thomas, 1982) and determined by titration with 0.05 N sodium hydroxide (NaOH) using phenolphthalein as an indicator. The effective cation exchange capacity (ECEC) was calculated as the total sum of exchangeable bases and total exchangeable acidity.

The soil was moderately acidic (with pH value of 5.6) and sandy loam in texture (Table 1). The total N of was low (0.7 g kg⁻¹) as the value was below the critical level of 1.6-2.0 g kg⁻¹ while the available P values of the soil (5 mg kg⁻¹) was also below the critical level of 7-20 mg kg⁻¹. The K status of the soil (0.1 cmol kg⁻¹) was less than the critical level of 0.31 cmol kg⁻¹. The Ca content of the soil (1.6 cmol kg⁻¹) is below the critical value of 2.5 cmol kg⁻¹. The Mg content (0.4 cmol kg⁻¹) is moderate because it is within the critical value of 0.2-0.4 cmol kg⁻¹. The K content (0.1 cmol kg⁻¹) is low as it is below the critical level of 0.16-0.25 cmol kg⁻¹. The soil was generally low in organic carbon (7.2 g kg⁻¹) because it was below the critical level of 10-14 g kg⁻¹ (FFD, 2012).

Table 1. Physical and chemical properties of pre-cropping soil

Parameters	Value
pH (H ₂ O) (1:1)	5.60
OC, g kg ⁻¹	7.20
Total N, g kg ⁻¹	0.70
Available P, mg kg ⁻¹	5.00
Exchangeable cations, cmol kg ⁻¹	
Ca ⁺⁺	1.60
Mg ⁺⁺	0.40
K ⁺	0.10
Na ⁺	0.20
Exchangeable acidity (Al ³⁺ +H ⁺)	0.13
ECEC	2.43
Particle size, g kg ⁻¹	
Sand	776.0
Silt	124.8
Clay	109.2
Textural class	Sandy loam

Results

The results of the effect of treatments on the plant height of NH47-4 and LD88 presented in Table 2 showed that they were significantly affected by fertilizer treatments compared with the control. At the main planting, the highest plant height (51.2 cm) of NH47-4 was obtained from NPK at 60 kg N ha⁻¹ while the highest plant height of LD88 was obtained from CPH+PM at 100 kg N ha⁻¹. The control gave the least plant height of NH47-4 and LD88 (29.5 and 34.4 cm respectively). At the residual planting, there were no significant differences in the plant height of NH47-4 across all the treatments. However, the plant height of LD88 was significantly affected by fertilizer treatments. The highest plant height (50.1 cm) was obtained from CPH+PM+NL at 100 kg N ha⁻¹ which was significantly higher than all the NPK treated plants and the control (33.3 cm).

The number of leaves of NH47-4 was significantly affected by fertilizer treatments in main planting but the difference was not significant in LD88 (Table 2). The highest number of leaves (7.3) of NH47-4 obtained from NPK at 40 kg N ha⁻¹ was not significantly higher than most of the fertilizer treatments but significantly

higher than CPH+PM+NL at 100 kg N ha⁻¹ (6.0), CPH+PM at 50 kg N ha⁻¹ (5.7), CPH+PM+NL at 50 kg N ha⁻¹ (5.5) and the control (5.3). However, at residual planting, there were no significant difference in the number of leaves of both NH47-4 and LD88 across all the treatments. The stem girth of NH47-4 was not significantly affected by fertilizer treatment at both main and residual planting (Table 2). However, the stem girth of LD88 was significantly affected in both main and residual planting. The highest stem girth obtained from NPK at 50 kg N ha⁻¹ (5.9 mm) was significantly higher than CPH+PM+NL at 50 kg N ha⁻¹ (4.5 mm) and the control (4.2 mm) in the main planting. At the residual planting, LD88 treated with NPK at 50 kg N ha⁻¹ gave the highest stem girth (5.9 mm) which was significantly higher than that of CPH+PM+NL at 50 kg N ha⁻¹ (4.5 mm) and the control (4.2 mm).

Table 2. Plant height (cm), number of leaves and stem girth (mm) of okra as influenced by applications of compost and NPK fertilizer at 6 weeks after sowing during the main and residual planting

Treatment	Main			Residual						
	Plant height	No of leaves	Stem girth	Plant height	No of leaves	Stem girth				
NH47-4										
Control	29.5	i	5.3	e	4.1	27.0	4.7	4.1		
CPH+PM+NL 25 KgN	40.2	de	6.8	abc	4.5	31.9	5.3	4.5		
CPH+PM+NL 50 KgN	37.1	ef	5.5	e	4.6	33.0	4.5	4.6		
CPH+PM+NL 75 KgN	47.5	abc	6.5	abcd	5.0	37.4	4.7	5.0		
CPH+PM+NL 100 KgN	43.2	bcd	6.0	bcd	4.9	32.2	4.7	4.9		
CPH+PM 25 KgN	33.4	fgh	6.3	abcd	4.9	34.5	5.0	4.9		
CPH+PM 50 KgN	42.4	cd	5.7	cd	5.1	37.3	4.3	5.1		
CPH+PM 75 KgN	40.2	de	6.2	abcd	4.9	36.0	5.0	4.9		
CPH+PM 100 KgN	43.8	bcd	7.0	ab	5.1	37.5	4.8	5.1		
CPH+NL 25 KgN	31.5	gh	6.2	abcd	5.6	28.7	5.2	5.6		
CPH+NL 50 KgN	46.2	abc	7.2	ab	5.1	40.3	5.2	5.1		
CPH+NL 75 KgN	42.4	cd	6.8	abc	4.8	39.1	5.0	4.8		
CPH+NL 100 KgN	35.9	efg	6.5	abcd	5.6	40.0	4.7	5.6		
NPK 40 KgN	45.3	bcd	7.3	a	4.9	30.4	4.5	4.9		
NPK 50 KgN	47.9	ab	6.2	abcd	5.2	34.3	5.2	5.2		
NPK 60 KgN	51.2	a	6.3	abcd	5.2	35.9	4.8	5.2		
				ns		ns	ns	ns		
LD88										
Control	34.4	f	6.5		4.2	33.3	e	4.2	4.2	c
CPH+PM+NL 25 KgN	41.4	e	6.3		5.0	41.0	bcde	4.3	5.0	abc
CPH+PM+NL 50 KgN	41.0	e	6.3		4.5	43.0	abcd	4.0	4.5	bc
CPH+PM+NL 75 KgN	42.2	de	5.7		5.1	45.9	abc	4.8	5.1	abc
CPH+PM+NL 100 KgN	43.5	cde	5.5		5.3	50.1	a	5.0	5.3	ab
CPH+PM 25 KgN	42.7	de	6.2		5.4	38.2	bcde	4.7	5.4	ab
CPH+PM 50 KgN	46.5	bcde	6.8		4.9	40.4	bcde	5.0	4.9	abc
CPH+PM 75 KgN	43.9	cde	6.5		5.5	44.2	abc	4.7	5.5	a
CPH+PM 100 KgN	54.5	a	6.8		5.6	44.2	abc	4.5	5.6	a
CPH+NL 25 KgN	39.5	ef	5.8		5.0	46.2	ab	5.0	5.0	abc
CPH+NL 50 KgN	50.0	abc	5.8		5.4	34.3	de	4.2	5.4	ab
CPH+NL 75 KgN	43.5	cde	6.8		5.7	46.7	ab	4.5	5.7	a
CPH+NL 100 KgN	52.3	ab	5.8		5.2	40.8	bcde	5.2	5.2	abc
NPK 40 KgN	43.7	cde	5.8		5.0	32.9	e	5.0	5.0	abc
NPK 50 KgN	48.8	abcd	6.3		5.9	37.2	cde	5.2	5.9	a
NPK 60 KgN	54.3	a	6.5		5.3	39.3	bcde	4.8	5.3	ab
				ns				ns		

ns - not significant; * - significant. Means with same letter (s) in a column under the same treatment are not significantly different at 5 % level of probability by Duncan's Multiple Range Test (DMRT). CPH= Cocoa pod husk, PM= Poultry manure, NL= Neem leaf

The dry matter yield of NH47-4 and LD88 were significantly affected by fertilizer treatments in both main and residual planting (Table 3). At the main planting, the highest dry matter yield of NH47-4 (16.7g) obtained from NPK at 60 kg N ha⁻¹ was not significantly higher than CPH+PM at 75 kg N ha⁻¹ (15.5 g), CPH+PM+NL at 75 kg N ha⁻¹ (15.0 g), CPH+PM+NL at 50 kg N ha⁻¹ (14.5 g) and CPH+PM+NL at 100 kg N ha⁻¹ (14.4 g) but significantly higher than the other treatments and control which gave the least value (6.5 g). The

highest dry matter yield of LD88 (19.1g) obtained from CPH+PM at 75 kg N ha⁻¹ was not significantly higher than CPH+PM at 50 kg N ha⁻¹ but significantly higher than other treatments and control which gave the least value (8.3 g). At the residual planting, the highest dry matter yield of NH47-4 (7.5 g) was obtained from CPH+NL at 100 kg N ha⁻¹ while the highest yield of LD88 (9.6g) was obtained from CPH+ PM at 75 kg N ha⁻¹.

Table 3. Dry matter yield (g/plant) of okra as influenced by compost and NPK fertilizer in main and residual planting

Treatment	Main			Residual		
	Shoot	Root	Total	Shoot	Root	Total
NH47-4						
Control	5.8 f	0.7	6.5 f	4.6 ef	0.5 de	5.1 de
CPH+PM+NL 25 KgN	13.0 bc	0.8	13.9 bc	5.3 cde	0.6 cde	5.9 bcd
CPH+PM+NL 50 KgN	13.6 abc	0.9	14.5 abc	5.2 cdef	1.3 a	6.5 abcd
CPH+PM+NL 75 KgN	14.0 abc	1.0	15.0 abc	5.7 bc	0.9 b	6.6 abcd
CPH+PM+NL 100 KgN	13.6 abc	0.8	14.4 abc	6.2 ab	0.7 bcd	6.9 ab
CPH+PM 25 KgN	11.8 cd	0.9	12.7 cd	5.0 cdef	0.7 bcd	5.6 bcd
CPH+PM 50 KgN	13.0 bc	0.9	13.9 bc	5.7 bc	0.6 cde	6.3 abcd
CPH+PM 75 KgN	14.4 ab	1.1	15.5 ab	5.3 cde	0.7 bcd	6.0 abcd
CPH+PM 100 KgN	12.3 bc	0.9	13.1 bc	6.0 b	0.7 bcd	6.8c ab
CPH+NL 25 KgN	9.4 de	0.7	10.1 e	4.6 ef	0.7 cd	5.3 cde
CPH+NL 50 KgN	9.8 de	0.6	10.5 de	5.0 cdef	0.7 bcd	5.7 bcd
CPH+NL 75 KgN	8.3 e	0.8	9.1 e	4.7 ef	0.4 e	5.1 de
CPH+NL 100 KgN	8.1 e	0.7	8.9 e	6.7 a	0.8 bc	7.5 a
NPK 40 KgN	8.9 e	0.9	9.8 e	4.5 f	0.8 bc	5.3 cde
NPK 50 KgN	9.5 de	0.8	10.3 de	5.0 cdef	0.8 bc	4.1 e
NPK 60 KgN	15.9 a	0.8	16.7 a	5.0 cdef	0.8 bc	5.8 bcd
		ns				
LD88						
Control	7.5 f	0.8 cd	8.3 f	3.6 j	0.4 d	4.0 j
CPH+PM+NL 25 KgN	9.2 ef	0.9 bc	10.1 def	5.2 ghi	0.6 b	5.8 ghi
CPH+PM+NL 50 KgN	8.6 f	1.0 bc	9.6 ef	4.8 hi	0.4 d	5.2 gh
CPH+PM+NL 75 KgN	9.4 def	1.3 ab	10.7 de	5.8 efg	1.0 a	6.8 def
CPH+PM+NL 100 KgN	9.4 def	1.2 ab	10.6 def	6.1 defg	0.9 a	6.9 de
CPH+PM 25 KgN	11.2 cde	0.8 cd	12.0 cd	6.9 bcd	0.5 c	7.4 d
CPH+PM 50 KgN	16.2 ab	1.2 ab	17.4 ab	5.9 efg	0.6 b	6.4 efg
CPH+PM 75 KgN	17.8 a	1.3 ab	19.1 a	8.6 a	1.0 a	9.6 a
CPH+PM 100 KgN	16.5 ab	1.2 ab	17.6 ab	7.5 bc	0.8 a	8.3 bc
CPH+NL 25 KgN	8.6 f	0.7 cd	9.3 ef	6.2 def	0.5 c	6.7 def
CPH+NL 50 KgN	9.8 cdef	0.9 bc	10.8 def	7.8 b	0.6 b	8.4 b
CPH+NL 75 KgN	9.3 ef	1.0 bc	10.3 def	6.6 cde	0.6 b	7.2 de
CPH+NL 100 KgN	11.9 c	1.2 ab	13.1 c	7.2 bc	0.4 d	7.5 cd
NPK 40 KgN	11.7 cd	1.2 ab	13.2 c	5.5 fgh	0.5 c	5.9 fgh
NPK 50 KgN	8.3 f	0.5 d	8.8 f	4.6 i	0.5 c	5.1 i
NPK 60 KgN	14.8 b	1.6 a	16.4 b	5.5 fgh	0.4 d	6.0 fgh

ns - not significant. Means with same letter (s) in a column under the same treatment are not significantly different at 5 % level of probability by Duncan's Multiple Range Test (DMRT). CPH= Cocoa pod husk, PM= Poultry manure, NL= Neem leaf

The N, P and K uptake of the two varieties were significantly enhanced by treatments in both main and residual planting (Table 4). In the main planting, CPH+PM at 25 kg N ha⁻¹ gave the highest N uptake of NH47-4 (190.6 mg/plant) which was not significantly different from value (171.0 mg/plant) obtained from CPH+PM+NL 50 kg N ha⁻¹ but significantly higher than other fertilizer treatments and control which gave the least value (96.1 mg/plant). The highest N uptake of LD88 (192.7 mg/plant) obtained from CPH+PM at 50 kg N ha⁻¹ was not significantly higher than CPH+PM at 75 kg N ha⁻¹ (177.2 mg/plant) and CPH+PM at 100 kg N ha⁻¹ but significantly higher than other treatments.

The highest P uptake of NH47-4 (29.9 mg/plant) obtained from CPH+PM+NL at 100 kg N ha⁻¹ was not significantly higher than that of CPH+PM at 50 kg N ha⁻¹ (28.7 mg/plant) but significantly higher than other treatments. The P uptake of LD88 (28.1 mg/plant) obtained from CPH+PM at 100 kg N ha⁻¹ was significantly higher than other treatments. The mean uptake of K of NH47-4 (144.6 mg/plant) obtained from CPH+PM+NL at 100 kg N ha⁻¹ was not significantly higher than the value obtained from CPH+PM+NL at 75 kg N ha⁻¹ (125.5 mg/plant) but significantly higher than other treatments. The K uptake of LD88 (164.4 mg/plant) obtained from CPH+PM at 100 kg N ha⁻¹ was not significantly higher than CPH+NL at 50 kg N ha⁻¹

(158.8 mg/plant), CPH+PM at 50 kg N ha⁻¹ (150.4 mg/plant), CPH+PM at 75 kg N ha⁻¹ (146.3 mg/plant) and CPH+NL at 25 kg N ha⁻¹ (137.7 mg/plant) but significantly higher than other treatments.

In the residual planting, the highest N uptake of NH47-4 (74.2 mg/plant) obtained from CPH+PM at 100 kg N ha⁻¹ was not significantly different from CPH+PM+NL at 50 kg N ha⁻¹ (74.1 mg/plant), CPH+NL at 100 kg N ha⁻¹ (70.2 mg/plant) and CPH+PM at 25 kg N ha⁻¹ but significantly different from other treatments. The highest N uptake of LD88 (84.0 mg/plant) obtained from CPH+NL at 50 kg N ha⁻¹ was significantly different from other treatments. The highest P uptake of NH47-4 (19.9 mg/plant) obtained from CPH+NL 50 kg N ha⁻¹ was not significantly different from CPH+NL (19.2 mg/plant) but significantly different from other treatments. The P uptake of LD88 (14.8 mg/plant) obtained from CPH+PM at 100 kg N ha⁻¹ was significantly higher than all the treatments. The highest K uptake of NH47-4 (98.0 mg/plant) obtained from CPH+NL at 100 kg N ha⁻¹ was significantly different from other treatments. Also, LD88 had the highest K uptake (97.7 mg/plant) obtained from CPH+NL at 25 kg N ha⁻¹ was not significantly different from CPH+NL at 50 kg N ha⁻¹ (95.3 mg/plant) but significantly different from the other treatments. The control gave the least N, P and K uptake of NH47-4 and LD88 in both main and residual planting.

Table 4. Nutrient uptake (mg/plant) of okra as influenced by applications of compost and NPK fertilizer during the main and residual planting

Treatment	Main						Residual					
	N		P		K		N		P		K	
NH47-4												
Control	96.1	fgh	13.2	efg	67.5	gh	33.2	ef	4.5	f	30.4	g
CPH+PM+NL 25 KgN	130.1	cdef	16.6	defg	103.2	bc	38.4	def	7.1	def	56.2	cdef
CPH+PM+NL 50 KgN	171.0	ab	23.2	bcd	106.5	bc	74.1	a	10.5	cd	70.3	c
CPH+PM+NL 75 KgN	137.5	bcde	23.4	bcd	125.5	ab	40.8	cdef	10.4	cd	66.3	cd
CPH+PM+NL 100 KgN	139.4	bcde	29.9	a	144.6	a	45.9	cde	17.2	b	81.8	b
CPH+PM 25 KgN	190.6	a	21.1	bcde	115.2	de	68.0	ab	9.4c	de	35.6	fg
CPH+PM 50 KgN	120.3	defg	28.7	ab	121.5	d	55.3	bcd	13.5	bc	50.1	cdefg
CPH+PM 75 KgN	155.0	bc	26.7	bc	107.6	def	40.7	cdef	15.2	c	38.8	efg
CPH+PM 100 KgN	152.2	bcd	15.7	defg	115.3	de	74.2	a	8.1	def	58.7	cde
CPH+NL 25 KgN	73.1	h	9.3	g	43.2	h	49.4	cde	7.4	def	33.7	g
CPH+NL 50 KgN	108.7	efgh	14.2	efg	77.3	fgh	41.8	cdef	19.9	a	40.2	efg
CPH+NL 75 KgN	103.6	fgh	18.9	cdef	85.6	efg	58.6	bcd	19.2	a	48.2	defg
CPH+NL 100 KgN	102.7	fgh	11.5	fg	154.4	c	70.2	ab	9.7	cde	98.0	a
NPK 40 KgN	94.2	gh	9.7	g	66.1	gh	34.7	ef	5.3	ef	35.7	fg
NPK 50 KgN	93.3	gh	13.4	efg	83.8	efg	24.7	f	5.3	ef	32.6	g
NPK 60 KgN	152.9	bcd	20.2	cde	96.6	defg	44.8	cde	7.0	def	33.6	g
LD88												
Control	60.1	g	12.9	e	68.8	g	28.3	f	6.1	de	38.3	d
CPH+PM+NL 25 KgN	120.3	de	13.2	de	124.9	bcde	69.2	b	6.3	de	67.3	bc
CPH+PM+NL 50 KgN	118.1	de	17.3	cde	121.3	cde	63.7	bc	9.3	bcd	58.4	c
CPH+PM+NL 75 KgN	106.8	ef	18.1	cde	120.2	cde	48.7	de	11.5	b	72.8	bc
CPH+PM+NL 100 KgN	108.8	ef	13.8	de	139.9	abcd	49.8	de	9.1	bcd	87.0	b
CPH+PM 25 KgN	118.6	de	16.9	cde	114.8	def	50.7	de	10.4	bc	57.9	c
CPH+PM 50 KgN	192.7	a	12.5	e	150.4	ab	64.8	bc	4.5	e	36.5	d
CPH+PM 75 KgN	177.2	ab	24.7	b	146.3	abc	60.1	bcd	11.1	b	66.5	bc
CPH+PM 100 KgN	176.2	ab	28.1	a	164.4	a	55.1	cd	14.8	a	68.7	bc
CPH+NL 25 KgN	85.1	f	12.8	e	137.7	abcd	41.6	e	9.2	bcd	97.7	a
CPH+NL 50 KgN	110.6	def	15.1	cde	158.8	a	84.0	a	11.8	b	95.3	a
CPH+NL 75 KgN	102.8	def	16.4	cde	112.5	def	65.4	bc	11.5	b	77.7	bc
CPH+NL 100 KgN	135.3	cd	19.6	bcd	114.4	def	56.6	cd	11.3	b	65.0	c
NPK 40 KgN	157.8	bc	19.4	bcd	86.3fg		71.2	b	7.7	cde	70.0	bc
NPK 50 KgN	123.4	de	12.6	e	59.3	g	70.9	b	6.9	de	33.1	d
NPK 60 KgN	156.7	bc	21.3	bc	99.7	ef	56.8	cd	7.7	cde	26.8	d

ns - not significant; * - significant. Means with same letter (s) in a column under the same treatment are not significantly different at 5 % level of probability by Duncan's Multiple Range Test (DMRT). CPH= Cocoa pod husk, PM= Poultry manure, NL= Neem leaf

The effect of treatments was significant on all the chemical properties determined in soil planted with NH47-4 in the main planting (Table 5). The pH values of all the treatments increased with fertilizer treatments with the highest value (7.1) obtained from CPH+PM+NL at 50 kg N ha⁻¹, CPH+PM at 50 kg N ha⁻¹ and CPH+NL at 50 kg N ha⁻¹ while the least value was obtained from the control (6.0). Also, the pH of soil planted with LD88

increased with CPH-based fertilizer compared to the control. The organic carbon of the soil planted with NH47-4 increased from the initial value of 7.2 to between 21.2 and 24.6 g kg⁻¹ with CPH+PM+NL at 25 and 50 kg N ha⁻¹ respectively. However, the organic carbon of soil planted with LD88 were not significantly different among the CPH-based fertilizer but significantly higher than all the NPK rates (6.6 g kg⁻¹) and control (17.0 g kg⁻¹). There were significant increase in the N content of the soil planted with NH47-4 with the application of fertilizer. The highest N content (1.2 g kg⁻¹) obtained from CPH+PM+NL at 75 kg N ha⁻¹ was significantly higher than some of the other fertilizer treatments and control (0.67 g kg⁻¹). There were no significant differences in the N content of soil planted with LD88. The P, Ca, Mg K and Na contents of soil planted with NH47-4 were significantly enhanced by the application of fertilizer; the control gave the lowest value of P (3 mg kg⁻¹) and Mg (0.4 cmol kg⁻¹). Also, the P, Ca, Mg and K content of soil planted with LD88 were significantly enhanced with fertilizer treatments except Na that was not significantly enhanced.

Table 5. Effects of applications of compost and NPK fertilizer on soil chemical properties after the main planting

Treatment	pH		Org.C		N		P		Ca		Mg		K		Na	
	(H ₂ O)		(g kg ⁻¹)		(mg kg ⁻¹)		(mg kg ⁻¹)		(cmol kg ⁻¹)		(cmol kg ⁻¹)		(cmol kg ⁻¹)		(cmol kg ⁻¹)	
NH47-4																
Control	6.0	e	15.1	e	0.67	d	3	c	2.3	b	0.4	f	0.1	b	0.2	d
CPH+PM+NL 25 KgN	6.8	bc	21.2	d	1.03	abc	6	a	2.2	b	0.9	e	0.1	b	0.2	d
CPH+PM+NL 50 KgN	7.1	a	24.6	a	1.03	abc	5	ab	2.3	b	0.8	e	0.2	a	1.7	a
CPH+PM+NL 75 KgN	6.8	bc	23.4	a	1.20	a	5	ab	2.3	b	1.3	c	0.2	a	1.1	b
CPH+PM+NL 100 KgN	7.0	ab	22.6	b	1.00	abc	5	ab	2.3	b	2.2	b	0.2	a	0.2	d
CPH+PM 25 KgN	6.6	d	20.9	d	0.80	cd	5	ab	2.3	b	0.8	e	0.1	b	0.2	d
CPH+PM 50 KgN	7.1	a	24.5	a	1.07	ab	5	ab	2.3	b	1.0	d	0.2	a	0.7	c
CPH+PM 75 KgN	6.9	bc	23.6	a	1.07	ab	5	ab	2.3	b	1.3	c	0.2	a	1.1	b
CPH+PM 100 KgN	7.0	ab	21.8	c	0.97	abc	5	ab	2.3	b	2.3	b	0.2	a	0.2	d
CPH+NL 25 KgN	6.7	cd	21.4	d	0.87	bc	4	bc	2.2	b	0.8	e	0.1	b	0.2	d
CPH+NL 50 KgN	7.1	a	24.3	a	1.07	ab	5	ab	2.3	b	0.8	e	0.2	a	1.7	a
CPH+NL 75 KgN	6.9	bc	23.6	a	1.03	abc	5	ab	2.2	b	1.3	c	0.1	b	1.2	b
CPH+NL 100 KgN	6.9	bc	21.6	c	0.90	c	5	ab	2.5	a	2.2	b	0.2	a	0.2	d
NPK 40 KgN	6.7	cd	23.8	a	0.67	d	3	c	2.2	b	2.4	a	0.2	a	0.2	d
NPK 50 KgN	6.7	cd	22.4	b	0.70	d	4	bc	2.2	b	2.2	b	0.2	a	0.2	d
NPK 60 KgN	6.8	c	21.7	c	0.73	d	6	a	2.2	b	2.2	b	0.1	b	0.2	d
LD88																
Control	6.1	c	17.0	c	0.7		5	a	2.3	cd	1.0	d	0.1	b	0.2	
CPH+PM+NL 25 KgN	6.8	ab	22.6	a	0.9		5	a	2.2	cd	1.1	c	0.2	a	0.2	
CPH+PM+NL 50 KgN	6.9	a	22.6	a	0.9		2	c	2.3	cd	1.1	c	0.2	a	0.2	
CPH+PM+NL 75 KgN	6.9	a	22.9	a	1.0		3	b	2.4	c	1.1	c	0.2	a	0.2	
CPH+PM+NL 100 KgN	6.9	a	22.7	a	1.0		5	a	2.3	cd	1.0	d	0.2	a	0.2	
CPH+PM 25 KgN	6.8	ab	22.9	a	0.9		5	a	2.3	cd	1.1	c	0.2	a	0.2	
CPH+PM 50 KgN	6.9	a	22.4	a	0.9		2	c	2.3	cd	1.1	c	0.2	a	0.2	
CPH+PM 75 KgN	6.7	bc	22.7	a	1.0		4	b	2.3	cd	1.1	c	0.2	a	0.2	
CPH+PM 100 KgN	6.9	a	22.0	a	0.8		5	a	3.0	a	1.9	a	0.2	a	0.2	
CPH+NL 25 KgN	6.8	ab	22.8	a	0.9		5	a	2.8	ab	1.1	c	0.2	a	0.2	
CPH+NL 50 KgN	6.7	bc	22.4	a	0.8		2	c	2.4	c	1.1	c	0.2	a	0.2	
CPH+NL 75 KgN	6.7	bc	22.2	a	1.0		4	b	2.4	c	1.1	c	0.2	a	0.2	
CPH+NL 100 KgN	6.9	a	23.0	a	0.9		5	a	2.7	b	1.1	c	0.2	a	0.2	
NPK 40 KgN	6.6	c	19.0	b	0.8		5	a	1.9	e	1.2	b	0.1	b	0.2	
NPK 50 KgN	6.6	c	18.6	b	0.9		3	b	2.4	c	1.2	b	0.2	a	0.2	
NPK 60 KgN	6.6	c	18.6	b	0.8		5	a	2.1	de	1.1	c	0.1	b	0.2	
															ns	ns

ns - not significant; * - significant. Means with same letter (s) in a column under the same treatment are not significantly different at 5 % level of probability by Duncan's Multiple Range Test (DMRT). CPH= Cocoa pod husk, PM= Poultry manure, NL= Neem leaf

After the residual planting, the effect of compost and NPK fertilizer application was significant on all the parameters measured except K in soil planted with NH47-4 (Table 6). All the CPH-based fertilizer increased the pH of soil more than NPK and control. Soil applied with CPH+NL at 75 kg N ha⁻¹ had the highest pH (7.0) which was significantly higher than NPK at 40 kg N ha⁻¹ (6.3), 50 kg N ha⁻¹ (6.4), 60 kg N ha⁻¹ (6.3) and control (6.3). The same trend was observed in pH value of soil planted with LD88. The organic carbon and N

contents of soils planted with NH47-4 and LD88 were significantly enhanced by CPH-based fertilizer compared to NPK and control. Also P, Ca, Mg and Na were significantly enhanced by CPH-based fertilizer compared to control in soils planted with NH47-4 and LD88; however, there was no significant difference in the K content of the soil planted to either NH47-4 or LD88.

Table 6. Chemical properties of soil as influenced by compost and NPK fertilizer after the residual planting

Treatment	pH		Org.C		N		P		Ca	Mg		K	Na		
	(H ₂ O)		(g kg ⁻¹)		(mg kg ⁻¹)		(mg kg ⁻¹)			(cmol kg ⁻¹)					
NH47-4															
Control	6.3	e	9.7	f	0.1	g	3	e	3.8	e	5.3	i	0.1	0.5	ab
CPH+PM+NL 25 KgN	6.8	ab	17.8	bc	0.3	e	4	d	4.3	bcd	8.1	efgh	0.1	0.6	a
CPH+PM+NL 50 KgN	6.7	bc	22.7	a	0.4	d	6	b	5.1	abc	7.7	fgh	0.1	0.5	ab
CPH+PM+NL 75 KgN	6.6	c	17.3	bc	0.7	b	6	b	5.1	abc	8.6	defg	0.1	0.5	ab
CPH+PM+NL 100 KgN	6.8	ab	16.6	bc	0.8	a	6	b	5.8	a	7.9	fgh	0.1	0.6	a
CPH+PM 25 KgN	6.8	ab	16.0	bcd	0.5	c	5	c	5.3	ab	7.1	h	0.1	0.5	ab
CPH+PM 50 KgN	6.8	ab	14.9	cde	0.4	d	6	b	4.3	bcd	11.4	a	0.1	0.6	a
CPH+PM 75 KgN	6.9	ab	17.7	bc	0.3	e	5	c	5.3	ab	9.3	bcde	0.1	0.5	ab
CPH+PM 100 KgN	6.8	ab	18.5	b	0.4	d	7	a	5.1	abc	8.9	def	0.1	0.5	ab
CPH+NL 25 KgN	6.8	ab	18.2	b	0.3	e	5	c	4.4	bcd	10.6	ab	0.1	0.6	a
CPH+NL 50 KgN	6.7	bc	17.0	bc	0.5	c	4	d	5.7	a	10.4	abc	0.1	0.6	a
CPH+NL 75 KgN	7.0	a	16.9	bc	0.1	g	3	e	4.3	bcd	9.6	bcd	0.1	0.6	a
CPH+NL 100 KgN	6.7	bc	17.4	bc	0.5	c	4	d	4.3	bcd	11.2	a	0.1	0.5	ab
NPK 40 KgN	6.3	e	13.4	de	0.1	g	3	e	4.2	bcd	8.1	efgh	0.1	0.5	ab
NPK 50 KgN	6.4	d	13.7	de	0.1	g	6	b	3.9	cd	7.6	gh	0.1	0.4	c
NPK 60 KgN	6.3	e	12.0	ef	0.2	f	4	d	4.4	bcd	9.2	cde	0.1	0.5	ab
LD88															
Control	6.3	f	15.5	de	0.1	g	3	e	3.0	d	7.6	bc	0.1	0.5	b
CPH+PM+NL 25 KgN	6.7	bc	16.8	bcd	0.4	d	3	e	3.6	cd	9.9	b	0.1	0.5	b
CPH+PM+NL 50 KgN	6.9	a	16.8	bcd	0.5	c	5	c	5.1	abcd	8.7	abc	0.1	0.5	b
CPH+PM+NL 75 KgN	6.8	a	19.0	abc	0.7	a	7	a	3.2	d	7.5	c	0.1	0.6	a
CPH+PM+NL 100 KgN	6.8	ab	17.9	abcd	0.3	e	8	a	5.8	ab	7.9	bc	0.1	0.6	a
CPH+PM 25 KgN	6.8	ab	18.1	abcd	0.4	d	4	cd	5.4	abc	8.1	bc	0.1	0.5	b
CPH+PM 50 KgN	6.7	c	19.7	ab	0.6	b	5	c	6.3	a	8.5	abc	0.1	0.6	a
CPH+PM 75 KgN	6.9	a	17.6	abcd	0.4	d	5	c	4.5	abcd	8.8	abc	0.1	0.5	b
CPH+PM 100 KgN	6.8	ab	20.3	a	0.4	d	8	a	4.8	abcd	8.9	abc	0.1	0.5	b
CPH+NL 25 KgN	6.6	cd	19.1	abc	0.5		3	e	4.0	bc d	10.0	a	0.1	0.5	b
CPH+NL 50 KgN	6.8	ab	17.0	bcd	0.2	f	3	e	4.1	bcd	8.5	abc	0.1	0.6	a
CPH+NL 75 KgN	6.6	cd	16.3	cde	0.6	b	5	c	3.9	bcd	8.4	abc	0.1	0.5	b
CPH+NL 100 KgN	6.8	ab	16.3	cde	0.4	d	5	c	3.9	bcd	7.4	c	0.1	0.6	a
NPK 40 KgN	6.4	ef	16.1	cde	0.2	f	4	d	6.5	a	7.5	c	0.1	0.5	
NPK 50 KgN	6.3f		17.3	bcd	0.1	g	6	b	4.0	bcd	8.7	abc	0.1	0.5	b
NPK 60 KgN	6.5e		13.9	e	0.2	f	3	e	4.7	abcd	9.2	ab	0.1	0.5	b
ns															

ns - not significant; *- significant. Means with same letter (s) in a column under the same treatment are not significantly different at 5 % level of probability by Duncan's Multiple Range Test (DMRT)

Discussion

Inadequate availability of essential nutrients often limits the optimum performance of crops. Continuous cropping due to limited farm land has been found to reduce soil productivity (Li et al., 2016). Organic amendment not only influence soil properties, but also play a great role in the growth and development of plants and thus improve agricultural productivity (Lakhdar et al., 2011). In this study, okra growth was significantly improved as a result of added nutrient to the soil compared to the control. The observed taller plants and thicker plants with the application of compost and NPK fertilizer compared to the control was an indication of availability of more nutrients for plant growth (Kayode et al., 2018). Application of fertilizer increase the supply of nutrients which ultimately result in greater nutrient uptake. Plant growth and development depend on nutrient supply and in general enhances good yield. The findings with regard to

nutrient uptake by okra revealed that the uptake of N, P and K were higher with the application of composts and NPK but least with control plants indicating short supply of these nutrient elements to okra in the control plots. This is in agreement with the findings of [Kayode et al. \(2018\)](#) that the application of compost improved N, P and K uptake of okra. Shoot:root ratio is also influenced by the nutrient status of the soil. The shoot:root ratio is an index that indicates growth and dry matter accumulation between shoot and root. Dry matter production of okra was considerably enhanced by compost and NPK compared to control. [Taiwo et al. \(2002\)](#) reported that adequate supply of nutrients favored the development of plant height, stem girth and number of leaves which culminated in better production of dry matter than the low dry matter yield and nutrient uptake produced by the control. The compost improving the chemical properties of soil is "in agreement with [Blanchet et al. \(2016\)](#)" who found that organic amendment improved chemical properties of soil and provided a significant amount of P and K. Also [Achiba et al. \(2010\)](#) observed that application of organic amendment contributed to increasing the N content in soil. The higher soil pH in soil treated with CPH-based composts than NPK and control could be as a result of buffering capacity of CPH-based composts. This confirms the findings of [Adediran et al. \(1999\)](#), [Adeoye et al. \(2001\)](#), [Akande et al. \(2003\)](#) that application of organic materials could ameliorate acidic tropical soils and thereby improve crop production. The CPH-based composts produced higher build up of organic carbon and increased total N in the soil than the control. This is in agreement with the findings of [Moyinjesu \(2007\)](#) and [Ogunlade et al. \(2009\)](#) that cocoa pod husk increased soil organic matter and total N.

The CPH-based composts resulting in higher soil available P than NPK and control treatments indicated that P was released from the organic amendments. This is in agreement with the work of [Moyinjesu \(2007\)](#) that cocoa pod husk increased available P. The soil K, Ca and Mg were increased by the application of CPH compost and NPK relative to the control in the soil.

The better performance of okra observed during the residual planting in CPH-based treated plots over the control showed that composts had residual effects on soil. Therefore, nutrient availability especially N, P and K could affect the photosynthetic activities of the plant and subsequent production of dry matter. The result of residual nutrient uptake effects on okra showed that compost performed better than NPK fertilizer and control. This is in agreement with [Adediran et al. \(1999\)](#) who stated that compost had been found to supply plant nutrients in slowly available forms.

Conclusion

The composting of organic wastes is the most common technology of recycling and disposing them easily in a safe way. The present study has revealed that composting cocoa pod husk with other organic materials can improve growth and dry matter yield of okra and chemical properties of soil.

References

- [Achiba, W.B., Lakhdar, A., Gabteni, N., Laing, G.D., Verloo, M., Boeckx, P., Van Cleemput, O., Jedidi, N., Gallali, T., 2010. Accumulation and fractionation of trace metals in a Tunisian calcareous soil amended with farmyard manure and municipal solid waste compost. *Journal of Hazardous Materials* 176\(1-3\): 99-108.](#)
- [Adediran, J. A., Akande, M. O. and Adeoye, G. O. 1999. Comparative effectiveness of organic manures and complementary use of inorganic fertilizers on the growth and yield of maize. *African Soils* 29: 41-57.](#)
- [Adeoye, G.O., Sridhar, M.K.C., Ipinmoroti, R.R., 2001. Potassium recovery from farm wastes for crop growth. *Communications in Soil Science and Plant Analysis* 32\(15-16\): 2347-2358.](#)
- [Akanbi, W.B, Togun, A.O, Adediran, J.A, Ilupeju, E.A.O., 2010. Growth, dry matter and fruit yields components of okra under organic and inorganic sources of nutrients. *American-Eurasian Journal of Sustainable Agriculture* 4\(1\):1-13.](#)
- [Akande, M.O., Oluwatoyinbo, F.I., Adediran, J.A., Busari, K.W., Yusuf, I.O., 2003. Soil amendments affect the release of P from rock phosphate and the development and yield of okra. *Journal of Vegetable Crop Production* 9\(2\): 3-9.](#)
- [Akindoye, H.A, Adebayo, A.G, Aina, O.O., 2011. Growth and yield response of okra intercropped with live mulches. *Asian Journal of Agricultural Research* 5: 146-153.](#)
- [Akinyele, B.O, Osekita, O.S., 2006. Correlation and path coefficient analyses of seed yield attributes in okra \(*Abelmoschus esculentus* \(L.\) Moench\). *African Journal of Biotechnology* 5\(14\): 1330-1336.](#)
- [Blanchet, G., Gavazov, K., Bragazza, L., Sinaj, S., 2016. Responses of soil properties and crop yields to different inorganic and organic amendments in a Swiss conventional farming system. *Agriculture, Ecosystems & Environment* 230: 116-126.](#)
- [Bremner, J.M., 1996. Nitrogen-total. In: Methods of Soil Analysis. Part 3, Chemical Methods, Sparks, D.L., Page, A.L, Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T., Sumner, M.E. \(Ed.\). American Society of Agronomy, Soil Science Society of America. Madison, Wisconsin, USA. pp. 1085-1022.](#)

- FFD, 2012. Fertilizer use and Management Practices for crops in Nigeria. Federal Fertilizer Department (FFD). Federal Ministry of Agriculture and Rural Development (FMARD). Chude, V.O. Olayiwola, V.O., Daodu, S.O., Ekeoma. C. (Eds.). Abuja, Nigeria. pp.40-41.
- Hendershot, W.H., Lalonde, H., 1993. Ion exchange and exchangeable cations. In Soil sampling and methods of analysis, Carter, M. R., (Ed.) Vol. 19, London: Lewis Publishers. pp 167-176.
- IITA, 1982. Selected methods for soil analysis. International Institute of Tropical Agriculture (IITA). International Institute of Tropical Agriculture. IITA Series No. 7 Ibadan, Nigeria. pp.53-56.
- Kayode, C.O., Adeoye, G.O., Ezekiel-Adewoyin, D.T., Ayanfeoluwa, O.E., Ogunleti, D.O., Adekunle, A.F., 2018. Influence of cocoa pod husk-based compost on nutrient uptake of okra (*Abelmoschus esculentus* (L.) MOENCH) and soil properties on an Alfisol. *Communications in Soil Science and Plant Analysis* 49(17): 2113-2122.
- Lakhdar, A., Falleh, H., Ouni, Y., Oueslati, S., Debez, A., Ksouri, R., Abdelly, C., 2011. Municipal solid waste compost application improves productivity, polyphenol content, and antioxidant capacity of *Mesembryanthemum edule*. *Journal of Hazardous Materials* 191(1-3): 373-379.
- Li, X., Lewis, E.E., Liu, O., Li, H., Bai, C., Wang, Y., 2016. Effects of long-term continuous cropping on soil nematode community and soil condition associated with replant problem in strawberry habitat. *Scientific Report* 6: 30466.
- Moyinjesu, E.I., 2003. Incorporation of industrial biomass and their effect on growth, nutrient content of four successive crops of amaranthus. *Pertanika Journal of Tropical Agricultural Science* 26(1):49-58.
- Moyinjesu, E.I., 2007. Use of selected agro industrial biomass for enhancing seed, nitrogen, ash and crude protein quality of Amaranthus. *Emirates Journal of Food and Agriculture* 19(1): 13-21.
- Murphy, J., Riley, J.P., 1962. A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica Acta* 27:31-36.
- Nelson, D.W., Sommers, L.E., 1996. Total carbon and soil organic matter. In: Methods of Soil Analysis. Part 3, Chemical Methods. Sparks, D.L. Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T., Sumner, M.E. (Eds.). American Society of Agronomy, Soil Science Society of America. Madison, Wisconsin, USA. pp. 961-1010.
- Ogunlade, M.O., Oluyole, K.O., Aikpokpodion, P.O., 2009. An evaluation of the level of fertilizer utilization for cocoa production in Nigeria. *Journal of Human Ecology* 25(3): 175-178.
- Olaniyi, J.O., Akanbi, W.B., Olaniran, O.A., Ilupeju, O.T., 2010. The effect of organo-mineral and inorganic fertilizers on the growth, fruit yield, quality and chemical compositions of okra. *Journal of Animal and Plant Sciences* 9(1):1135-1140.
- Olsen, S.R., Dean, L.A., 1965. Phosphorus. In: Methods of Soil Analysis. Part 2, Chemical and Microbiological Properties. Norman, A.G., (Ed.). American Society of Agronomy - Soil Science Society of America, Madison, Wisconsin, USA. pp. 1035-1049.
- Osekita, O.S., Ariyo, O.J., Kehinde, O.B., 2000. Variation and inter - character association in segregating F3 populations arising from two crosses of okra (*Abelmoschus esculentus* (L.) Moench). *Moor Journal of Agricultural Research* 1(1): 32-36.
- Oyelade, O.J., Ade-Omowaye, B.I.O., Adeomi, V.F., 2003. Influence of variety on protein, fat contents and some physical characteristics of okra seeds. *Journal of Food Engineering* 57(2): 111-114.
- Sheldrick, B.H., Wang, C. 1993. Particle size distribution. In: Soil Sampling and Methods of Analysis. Carter, M.R. (Ed.). Canadian Society of Soil Science. Lewis Publishers, Boca Raton, FL, USA. pp. 499-511.
- Taiwo, L.B., Adediran, J.A., Ashaye, O.A., Odofoin, O.F., Oyadoyin, A.J., 2002. Organic okro (*Abelmoschus esculentus*): its growth, yield and organoleptic properties. *Nutrition and Food Science* 32(5): 180-183.
- Thomas, G.W., 1982. Exchangeable cations. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. Page, A.L, Miller, R.H., Keeney, D.R. (Eds.). 2nd Edition. Agronomy Monograph, vol. 9. American Society of Agronomy - Soil Science Society of America, WI, USA. pp. 159-165.
- van der Werf, A., 1996. Growth analysis and photoassimilate partitioning. In: Photoassimilate Distribution Plants and Crops Source-Sink Relationships. Zamsk, E., Schaffer, A.A., (Ed.). Marcel Dekker, New York, USA. pp 1-20.
- Xu, L., Niu, H., Xu, J., Wang, X., 2013. Nitrate-nitrogen leaching and modeling in intensive agriculture farmland in China. *The Scientific World Journal* Article ID 353086.