



## Sustaining Soil Organic Matter for Okra Production in a Forest Ecology of Nigeria

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### **Authors' contributions**

*This work was carried out in collaboration between both authors. Author MBA designed the study, supervised the work and wrote the first draft of the manuscript. Author RTA was involved in management of the experimental plots, data collection and managed analyses of data. Both authors read and approved the final manuscript.*

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### **ABSTRACT**

Okra production in Nigeria is particularly under smallholder and resource-poor farmers. This study therefore investigated the influence of aerobically composted cowdung (CWD), singly and in combination with Ogun rock phosphate (ORP) applications on the yield of okra and soil organic matter maintenance in typical forest ecology of Nigeria. The study was conducted during two different okra cropping seasons. The experiment was in a randomised complete block design of four, 27.0 m x 4.0 m blocks; each was divided into seven plots of 4.0 m x 3.0 m with an alley of 1.0 m between blocks and 1.0 m within plots. The treatment plots were made up of crop with: 100% CWD, 100% ORP, 20% CWD + 80% ORP, 40% CWD + 60% ORP, 60% CWD + 40% ORP, 80% CWD + 20% ORP and zero percent application served as control. The seven organic fertilizer treatments were applied at planting, and at the rates of 6.0 and 0.3 t ha<sup>-1</sup> for 100% CWD and 100% ORP respectively. Each of the treatments was replicated four times to give a total of 28 plots. Highest fresh okra mean yield of 22.9 ± 1.3 t ha<sup>-1</sup> obtained with 60% CWD + 40% ORP was only significantly (p = 0.05) different from 14.2 ± 1.2 t ha<sup>-1</sup> obtained with zero treatment application. This experiment was repeated two more times, but without treatment applications. About 5% reduction and over 100% increase in soil organic carbon and available P respectively were achieved after

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third consecutive okra cultivation. We therefore concluded that aerobically composted cowdung when complemented with Ogun rock phosphate enhanced the quantity of okra and soil organic matter of the study area.

*Keywords: Cowdung; forest ecology; Ogun rock phosphate; okra; resource-poor farmers.*

## 1. INTRODUCTION

Presently, the economy of Nigeria depends largely on the oil sector, but the global dwindling price of which is adversely affecting all her sectors. This is a deviation from an agrarian economy that Nigeria was known for in the 1960s. However, current drive by the Federal Government of Nigeria on agriculture has brought okra cultivation under smallholder farmers and its economic importance lies in the internal trade [1].

Okra (*Abelmoschus esculentus*) is commonly referred to as ladies fingers and belongs to the family *Malvaceae* [2]. Okra is mainly cultivated for its fresh pods [3,4] or leaves [5] when cooked and eaten in countries like Sudan, Egypt and Nigeria. The seeds of okra contain 47.4% oil [6]. Other essential composition of okra leaves and fruits have been reported by many researchers such as Akanbi et al. [7], Sanjeet et al. [8] and Adetuyi et al. [9].

The inherently low fertility of soils in the tropics, including Nigeria [10] requires high soil organic matter maintenance through the use of appropriate agronomic techniques in the management of its sandy and fragile soils. Organic materials such as composted cowdung and Ogun rock phosphate may be added to soil to replenish nutrient use, and zero tillage practice as traffic-reduction-measure on topsoil enhance soil productivity levels [1]. The present practice of arbitrary dumping of cowdung in many open spaces, particularly near abattoirs in the cities in Nigeria is un-aesthetic and could lead to outbreak and spread of diseases.

Soluble phosphate fertilizers that are commonly used to supplement P deficiency in soils during crop cultivation in Nigeria are very expensive for resource-poor farmers [11] and the need for suitable and environment-friendly alternative cannot be overemphasised. The abundance and chemical compositions of rock phosphate from different deposits in Nigeria have been well documented by Adesanwo et al. [12] and Obaje et al. [13]. Despite the agronomic potentials of this indigenous Ogun rock phosphate [14] there is dearth of information on its phosphorus

constituent addition to soil in okra production. This study therefore seeks to assess the influence of composted cowdung and Ogun rock phosphate addition for okra cultivation and soil organic matter maintenance in forest ecology of Nigeria.

## 2. MATERIALS AND METHODS

### 2.1 Location of the Study and Experimental Design

The experiment was conducted on a sandy loam soil at the Teaching and Research Farm of Obafemi Awolowo University (T&RFOAU), Ile-Ife, (07°32.250'N; 004°32.127'E) in Nigeria during the wet season of 2013. Fresh cowdung was collected from the Beef Unit of the T&RFOAU, aerobically composted for three months to obtain completely cured compost. Lumps of Ogun rock phosphate were obtained from the Department of Soil Science and Land Resources Management, OAU, Ile-Ife. Seeds of okra variety, NHAe 47-4 were purchased from National Horticultural Institute, Ibadan, Nigeria.

The piece of land for the experiment was ploughed twice to obtain good seedbed and the experiment laid out in randomised complete block design of four, 27.0 m x 4.0 m blocks; each was divided into seven plots of 4.0 m x 3.0 m with an alley of 1.0 m between blocks and 1.0 m within plots. The treatment plots were made up of crop with: 100% cowdung (CWD), 100% Ogun rock phosphate (ORP), 20% CWD + 80% ORP, 40% CWD + 60% ORP, 60% CWD + 40% ORP, 80% CWD + 20% ORP and zero percent manure addition served as control. Each of the treatments was replicated four times to give a total of 28 plots. The selected meteorological (soil temperature, rainfall and relative humidity) data for 2013 and 2014 of the study location are presented in Fig. 1(a-c).

### 2.2 Agronomic Study and Data Collection

Okra seeds were sown at three seeds per hole using 0.6 m x 0.3 m planting distance. The seven organic fertilizer treatments were applied at planting at the rates of 6.0 t ha<sup>-1</sup> and 0.3 t ha<sup>-1</sup> for 100% CWD and 100% ORP respectively. The

exact quantities of other organic fertilizer treatments were worked out and applied accordingly at planting. The okra seedlings were thinned to two per hole to give 111,111 plants population per hectare at two weeks after sowing. Manual weeding was carried out at intervals of 2, 5 and 7 weeks after sowing (WAS). The okra pods were harvested weekly from 45 days after sowing and continued till 15 WAS when the experiment was terminated. At each time of harvest, the fresh okra pods were counted and weighed to get the fresh weight per plot. Two repeat experiments were conducted on the same piece of land during the dry season of 2013 and wet season of 2014, but without additional organic fertilizers (composted cowdung and Ogun rock phosphate) as soil amendments.

### 2.3 Soil, Composted Cowdung and Ogun Rock Phosphate Analyses

Three composite soil samples to the depth 0-15 cm were collected with soil auger from the ploughed land using simple random technique, air-dried and sieved through 2.0 mm mesh. The pre-cropped soil, CWD and ORP samples were analyzed using standard methods as outlined by Page et al. [15] to determine their properties. The soil pH was determined in 1:1 soil-1 M KCl suspension using a glass electrode pH meter. Total nitrogen of the soil and CWD were determined by the macro-Kjeldahl method. Available phosphorus in the soil, CWD and ORP were extracted using Bray P1 method and P in the extractants was determined by colorimeter. The organic carbon in soil and CWD were determined using Walkley-Black wet oxidation method. Sodium ion,  $K^+$ ,  $Ca^{2+}$  and  $Mg^{2+}$  in the soil samples were extracted with 1 M ammonium acetate and the concentrations of  $Ca^{2+}$  and  $Mg^{2+}$  in the filtrates were read using the Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VGP, while  $Na^+$  and  $K^+$  were determined using the Gallenkamp Flame photometer. The addition of these cations gave the cation exchangeable capacity.

Post-cropping analyses of soils from different treatment plots were also carried out to determine the soil physical and chemical properties using standard methods as outlined by Page et al. [15].

### 2.4 Statistical Analyses

Data on yield of okra obtained were subjected to analysis of variance and their treatments means

to Bonferroni post-tests for their treatment effects evaluation using the GraphPad Prism 5.0 statistical software at 95% probability level. The selected post-cropped soil properties were subjected to descriptive analysis.

## 3. RESULTS AND DISCUSSION

### 3.1 Effects of Organic Amendments on Soil Properties

The pre-cropping soil pH was 6.1, an indication of a relatively acidic soil condition and particle size was sandy loam, typical of most African soils (Table 1). The soil organic carbon (SOC)  $12.6 \text{ g kg}^{-1}$  was moderately high, while total N  $1.3 \text{ g kg}^{-1}$  and available P  $2.0 \text{ mg kg}^{-1}$  were considered low for most vegetables and cereal crops in Nigeria [16]. Also, the pre-cropped soil cation exchangeable capacity, CEC ( $Na^+ + K^+ + Ca^{2+} + Mg^{2+}$ ) was  $2.22 \text{ cmol kg}^{-1}$ . There was 19.8% SOC build-up after the first okra cropping cycle which could be attributed to cowdung compost addition and litter-fall during the cultivation (Tables 2 and 3). The SOC reduced by 8.6 and 5.8% after the second and third okra cultivations respectively, but without treatment additions. However, by the end of third cultivation, SOC in the control plots had reduced by 75% (from  $12.6$  to  $4.2 \text{ g kg}^{-1}$ ). African low-activity clay soils are susceptible to rapid SOC reduction once the native vegetation is cleared [17].

Total N and available P also reduced with continuous okra cultivation on the same piece of land without further additions of soil amendment. The use of ORP in this study as a source of P for okra production enhanced P availability. Substantial amount of available P obtained following additions of crop residues and other organics to boost soil P had been observed by Özdemir et al. [18] and Soremi et al. [19]. Also, the earlier studies by Akinrinde and Obigbesan [10], Adesanwo et al. [12] and Obaje et al. [13] on the chemical composition of ORP could be of agronomic importance in crop husbandry, particularly when the soil in use is P deficient. Akande et al. [20] obtained enhanced P availability and uptake with addition of rock phosphate to soil, particularly in acidic condition. Addition of ORP increased the P availability in the soil by 490.0, 108.2, 102.8% after first, second and third okra cultivation respectively. Over 75% reduction in P availability despite single dose of ORP addition to soil could be attributed to P fixation ability.

Only the control plots (plots without CWD and ORP applications) had the CEC reduced by over 50% after third cultivation circle of the test crop. Ande et al. [21] had observed high rate of decomposition and mineralisation of inherent organic materials in a typical tropical soil. Also, the inherent adsorption potentials of most organic materials often used as soil amendments could have enhanced the CEC of the soil after okra cultivation as demonstrated in Table 2.

### 3.2 Effects of Organic Amendments on the Yield of Okra

In the wet season of 2013, the highest fresh okra mean yield of 22.9 t ha<sup>-1</sup> obtained with 60% CWD + 40% ORP treatment application was only significantly (*P* = 0.05) higher than 14.2 t ha<sup>-1</sup> obtained with no soil amendment additions (Table 4). However, in the subsequent dry season and with no new treatment applications to soil, relatively low mean yields were obtained which were also not significantly different. The mean yields of fresh okra pods from the same

plots during third cultivation in 2014 were comparable with the wet season of 2013 and higher than the dry season cultivation. Organic-based soil amendments have great potentials to release nutrients slowly into the soil for enhanced crop yield and long positive residual effect [22].

### 3.3 Effects of Selected Environmental Factors on the Yield of Okra

The selected monthly mean weather data (soil temperature, rainfall and relative humidity) collected from the OAU Teaching and Research Farm meteorological station for 2013 and 2014 are presented in Fig. 1. Okra production was enhanced with increase in rainfall and decrease in soil temperature as higher yields were obtained in the wet than dry seasons. Soil management is another environmental factor [17] such as the judicious use of organic N and P when complemented together enhanced the fresh yield of okra pods, particularly during the wet season [23].

**Table 1. Selected properties of pre-cropped soil, cowdung and Ogun rock phosphate**

Property	Soil	Cowdung	Ogun rock phosphate
pH (1:1 Soil : 1 M KCl)	6.1	-	-
Particle size	Sandy loam	-	-
Organic carbon (g kg <sup>-1</sup> )	12.6	118.3	-
Total nitrogen (g kg <sup>-1</sup> )	1.3	11.6	-
Available P (mg kg <sup>-1</sup> )	2.0	3.5	28.1
CEC (cmol kg <sup>-1</sup> )	2.22	-	-

**Table 2. Post-cropped soil organic carbon, available P contents and CEC in 2013 and 2014**

Treatment	Organic carbon (g kg <sup>-1</sup> )		Available P (mg kg <sup>-1</sup> )			CEC (cmol kg <sup>-1</sup> )			
	WS 2013	DS 2013	WS 2014	WS 2013	DS 2013	WS 2014	WS 2013	DS 2013	WS 2014
1	10.2	8.2	4.2	1.8	1.6	1.3	1.87	1.40	0.97
2	17.7	16.5	16.0	1.8	1.7	1.7	2.20	2.12	1.98
3	10.6	8.9	5.5	20.3	17.5	17.4	2.35	2.24	2.01
4	11.9	9.5	8.8	16.9	16.0	15.3	1.97	1.92	1.86
5	14.3	13.0	12.1	12.1	11.9	11.5	2.23	2.15	1.97
6	15.1	13.8	13.0	9.8	10.6	10.9	2.45	2.31	2.01
7	15.7	15.3	14.5	7.0	6.1	7.5	2.61	2.44	2.24

Legend: CWD = Composted cowdung, ORP = Ogun rock phosphate, WS = Wet season, DS = Dry season, Control = 1, 100% CWD = 2, 100% ORP = 3, 20% CWD + 80% ORP = 4, 40% CWD + 60% ORP = 5, 60% CWD + 40% ORP = 6, 80% CWD + 20% ORP = 7, CEC = Cation exchangeable capacity.

**Table 3. Percentage increase in selected post-cropped soil properties\* in 2013 and 2014**

Property	Wet season 2013	Dry season 2013	Wet season 2014
Organic carbon (g kg <sup>-1</sup> )	15.1 (+19.8%)	13.8 (-8.6%)	13.0 (-5.8%)
Available P (mg kg <sup>-1</sup> )	9.8 (+490.0%)	10.6 (+108.2%)	10.9 (+102.8%)
CEC (cmol kg <sup>-1</sup> )	2.45 (+10.4%)	2.31 (+4.1%)	2.01 (-9.5%)

Note: \* Post-cropped soil properties of the plots with treatment 60% CWD + 40% ORP

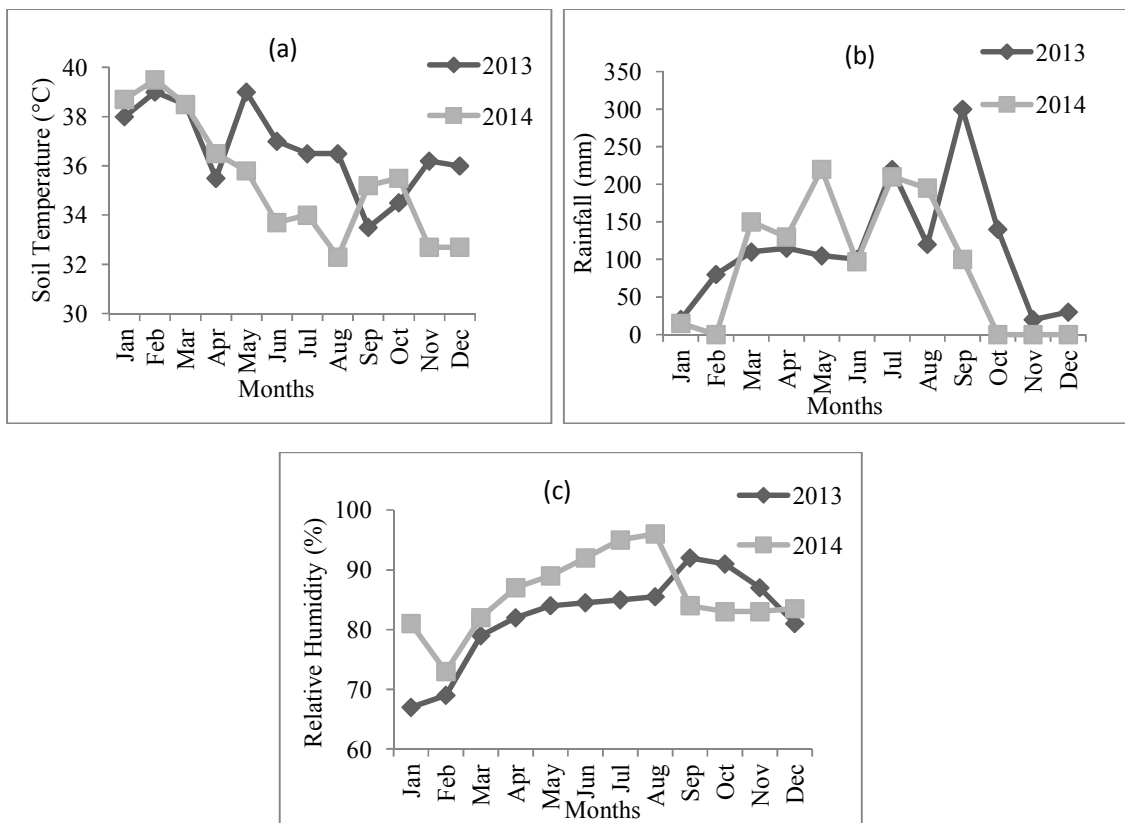
**Table 4. Fresh yield of okra ( $\pm$  SE t ha<sup>-1</sup>) in 2013 and 2014 cropping seasons**

Treatment	Wet season 2013	Dry season 2013	Wet season 2014
Control	14.2 $\pm$ 1.2b	11.8 $\pm$ 2.0ns	14.0 $\pm$ 1.3b
100% CWD	17.6 $\pm$ 0.9ab	16.6 $\pm$ 1.5ns	17.1 $\pm$ 1.5ab
100% ORP	16.7 $\pm$ 1.3ab	16.0 $\pm$ 1.2ns	16.0 $\pm$ 1.4ab
20% CWD+80% ORP	17.3 $\pm$ 1.4ab	16.0 $\pm$ 1.2ns	16.9 $\pm$ 1.6ab
40% CWD+60% ORP	17.8 $\pm$ 2.0ab	16.0 $\pm$ 1.6ns	17.3 $\pm$ 1.7ab
60% CWD+40% ORP	22.9 $\pm$ 1.3a	17.8 $\pm$ 1.4ns	22.4 $\pm$ 1.3a
80% CWD+20% ORP	20.9 $\pm$ 1.4ab	17.2 $\pm$ 1.4ns	20.3 $\pm$ 1.2ab

Mean with the same letter in the column are not significantly different by Bonferroni's Multiple Comparison Test at  $p = 0.05$

ns = Not significant at  $p = 0.05$

Legend: CWD = Composted cowdung, ORP = Ogun rock phosphate



**Fig. 1 (a)-(c). Monthly (a) soil temperature, (b) rainfall and (c) relative humidity of the study area (2013-2014)**

Source: OAU Teaching and Research Farm Meteorological Station, Ile-Ife, Nigeria

#### 4. CONCLUSION

We concluded that aerobically composted cowdung when complemented with Ogun rock phosphate could be effectively used to enhance the quantity of okra and to sustain the quality of soil organic carbon. In the area of environmental sanitation, the use of composted cowdung for soil organic carbon maintenance could also be

seen as a way of ‘cleaning the environment’ where heaps of such are still in abundance in many open spaces within the vicinity of abattoirs in Nigeria.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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