Amended Crop Wastes Compost Affect Soil Chemical Properties and Yield of Maize (*Zea mays* L.*)* in Nigeria Savanna

ABSTRACT

Aims: To evaluate the efficacy of poultry droppings amended cocoa pod husk and rice mill wastes, as a substitute for costly inorganic fertilizers on some soil properties and yield of maize.

Study design: Experiment was laid in randomized complete block design.

Place and Duration of Study: Two year field study was conducted at the Research Farm of the Cross River University of Technology during 2019 and 2020 cropping seasons.

Methodology: Two compost types: cocoa pod husk and rice mill wastes both amended with poultry droppings at the ratio of 3:1 for cocoa pod husk + poultry droppings and rice mill waste + poultry droppings respectively. Each compost type was applied at rate of 2.5, 5.0, 7.5 and 10 t ha^{-1} with absolute control (0 t ha^{-1} compost) and optimal control NPK 20.10.10 at 300 kg ha^{-1} making a total of 10 treatments replicated three times. The effect of the amendments were assessed on soil pH, OM, N, P, exch. Ca, K, Mg, EA, ECEC and maize yield.

Results: The compost rates increased soil pH, OM, N, P and the exch. K, Ca, EA, and ECEC over the pre-treatment soils and the controls. Cocoa pod compost amendments with poultry droppings at rate of 7.5 t ha^{-1} produced highest plant dry matter 8.21$gplant^{-1}$ and 8.08 $gplant^{-1}$ in 2019 and 2020 ($P = .05$) respectively and the highest grain yield of 3.92 t ha^{-1} and 3.89 t ha^{-1} respectively in 2019 and 2020. The least grain yield was in the absolute control, which yield was 0.38t ha^{-1} and 0.42 t ha^{-1}, respectively in 2019 and 2020.

Conclusion: Amended cocoa pod husk compost is a suitable soil amendment for optimum yield of maize and improvement of soil chemical properties in the study area and a substitute for mineral fertilizers for resource poor farmers.

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Keywords: C:N ratio, cocoa pod husk, rice husk, compost, inorganic fertilizer, maize yield.

Introduction

Soil fertility maintenance for sustainable food crop production remains the greatest challenge in tropical environments. This challenge has become more obvious with the vagaries of climate change. The unpredictable climate behaviour in recent years and unreliable forecast for weather has made soil modeling and management options not meeting crop yield targets. The use of inorganic fertilizers in the quest for sustainable soil productivity pose serious limitations due to its high cost, being uneconomical to resource poor farmers as well as gives hazardous environmental consequences. These includes acidification and nutrients imbalance in soils, reduced soil organic content, degradation of soil physical properties and increased rate of erosion due to instability of soil aggregates [1], deterioration of plant quality, diseases susceptibility and environmental pollution [2]. The basis of sustainability of tropical soils for crop production is the maintenance of soil organic matter. Organic based nutrients sources are noted for increasing crop yields as well as soil quality [3]. Nutrients contained in organic manures are released more slowly and are stored for a longer time in soil thus supporting better crop growth and development which ultimately leads to increased yields [4].

The validity of organic nutrient sources is its Carbon:Nitrogen (C:N) ratio. Some organic materials may be relatively resistant to microbial degradation and consequently exhibit very slow release of crop nutrient elements to the soil. Limited information is available on reducing the longer time of release of nutrients from some organic resources and integrated organics. Manures blending and integration have shown positive effects on some crops. [5] used poultry droppings and cowdung [6] used moringa leaf biomass and poultry droppings of which both findings showed increased soil organic matter, available P, Total N, ECEC and reduced Exchangeable acidity in addition to increased garden egg yield over the control and sole cow dung. Similar findings indicated that regular application of organic nutrient sources supplied all the various macro and micro nutrients and also improved soil physical and biological properties [7].

Maize is one of the major staple food crops in Nigeria that strive under different ecological conditions in the country. The crop provides major source of calories for both humans and livestock in Nigeria and the world over [8]. It was estimated that 1.5million hectares of maize are cultivated in Nigeria with yield of 1.9 million tonnes [9].

Poultry droppings as an agricultural waste, is a rich source of plants essential nutrients. [10,11] reported that poultry droppings is generally richer in nutrients than other animal manures, especially phosphorus (P).

Cocoa pod husk wastes are generated in tons as spent and usually discarded in concentrated heaps at dump sites in cacao farms. [12] reported that seed processing of cocoa generates huge amount of cocoa pod husk of about 67 % of the pod, amounting for an estimated 10(ten) tons per every ton of dry seeds processed. [13] reported that the main metallic ions in cocoa pod are Potassium (K) and Sodium (Na), followed by Mg > Ca > Cu > Fe. Rice husk is an abundant agricultural waste product from the rice milling industries. This organic waste has low N content and a high C:N ratio, making it less valuable due to the longer time required for its degradation and mineralization.

The problem of sustaining the yield of crops particularly staples like maize, forms the thrust of this research to evaluate composted cocoa pod and rice mill wastes amended with poultry droppings to meet the nutrients needs of this crop at all critical stages of demand.

MATERIALS AND METHODS

Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three times. Two compost types: composted cocoa pod husk (CCPH) and composted rice mill waste (CRMW) both amended with poultry droppings at the ratio of 3:1 for cocoa pod husk + poultry droppings and rice mill waste + poultry droppings, respectively. Each compost type was applied at rate of 2.5, 5.0, 7.5 and 10 t ha^{-1} with absolute control (0 t ha^{-1} compost) and optimal control NPK 20.10.10 at 300 $kgha^{-1}$. The 10 treatments were replicated 3 times in the field. Each plot size measured 4 m x 3 m (12 m^2) separated by 0.5 m between plots and 1 m between blocks (replicates). The gross experimental plot measured 22.0 m x 22.0m (484.00 m^2) or 0.0484 Ha.

Material and Compost preparation

The variety of the maize used was OBA Super 2

The cocoa pod husk was obtained from the Cocoa Research Institute of Nigeria farm breaking points at Ikom. The rice mill wastes were collected from the Obubra Rice Mill while the poultry droppings was obtained from the livestock farm of Cross River University of Technology. The materials were partitioned by weighing at a ratio of 3:1 and 3:1 of the cocoa pod + poultry droppings and rice mill waste + poultry droppings respectively. These compost ingredients were shredded and thoroughly mixed and formed into heaps. The heap was moisten with water, spread on plastic sheets and covered with plastic tarpaulin. The heaps temperature was monitored while turning was done in every 14 days for first 8 weeks and the compost was ready in 60 days. The compost was incorporated on prepared seed bed and allowed for two weeks before sowing of the maize seeds.

Cultural Practices

The maize was sown after two weeks of incorporation of the compost on the prepared seed beds at a spacing of 75cm x 50cm. After planting, manual weeding, insect pests control were carried out.

Data Collection

At the commencement of the experiment, composite soil sample was collected at random points within the experimental plot which was bulked using a soil auger at the 0 – 20 cm. Post cropping soil samples were collected from each treatment and replication at the end of the experiment. These samples were air dried and sieved through a 2mm mesh for laboratory analysis.

A net plot of inner ridges for each treatment was used with five tagged plants for growth and the yield components parameters while a plant from each net plot was cut at 8 WAP for dry matter. The plants were sampled for number of seeds per cob and weight of grains per unit area.

Routine analysis was conducted for the composite samples and the postharvest soil samples to determine the fertility properties of the soils.

Particle size distribution (PSD) was determined by the Bouyoucos (Hydrometer) method procedure by [14].

Soil pH was determined in both water and 0.1 N KCL in a ratio of 1:1 soil: water and 1:2.5 soil: KCl respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter [15]. Organic Matter was determined by the walkley-Black method [12], which involves the oxidation with dichromate and tetraoxosulphate vi acid (H_2SO_4). The excess was titrated against Ferrous Sulphate. The organic carbon was then calculated using the relationship: % Org.C = $\underline{N(Vi - V_2)}$ 0.3f

Where: **N =** Normality of Ferous Sulphate solution V_1 = Ml Ferrous Ammonium Sulphate for the black, V_2 = ml Ferrous Ammonium Sulphate for the sample, W = mass of sample = from F = correction factor = 1.33. % organic matter in soil = % org.C x 1.729. Total nitrogen in soil was determined by the macro Kjeldahl method [10]. The soil samples were digested with Tetraoxosulphate (Vi) acid ($H_2 S0_4$) after addition of excess caustic soda. This was distilled into a 2% Boric acid (H_3BO_4) and then titrated with 0.01 HCl. and the nitrogen was obtained from the relationship:

$$\% N = \frac{T \times M \times 14 \times 100}{N}$$

Available phosphorus was determined by Bray 1 method [16]. This involved mechanical shaking of the sample in an extracting solution then centrifuging the suspension at 2000 rotations per minutes for 10 minutes. Using Ascobic acid method, the percentage transmittance on the spectrophotometer at 660 nm wave length was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm and the extractable P of the soil was then calculated. Effective Cation Exchange Capacity (ECEC) and Exchangeable acidity (EA) were determined by the Kjeldahl distillation and titration method [17] using ammonium acetate solution the soil samples were leached then the soil washed with methyl alcohol and allowed to dry. The soil was then distilled in Kjeldahl operation in to a 4% Boric acid solution. The distillate was then titrated with standard solution of 0.1 N HCl.

Exchangeable cations was determined by ammonium acetate extraction method [17]. The soil samples were shaken for 2 hours then centrifuged at 2000 rpm for 5-10 minutes after decanting into a volumetric flask, ammonium acetate (30 ml) was added again and shaken for 30 minutes, centrifuged and the supernatant transferred into same volumetric flask. Atomic Absorption Spectrophotometer (AAS) was used to read the cations.

Statistical Analysis

Analysis of variance (ANOVA) for RCBD was performed on the maize growth and yield parameters using the computer software Genstat [18]. Dumcan Multiple Range Test (DMRT) was used to separate the means.

Results and Discussion

The soil properties before the organic amendment application (Table 1) showed that the soil was a sandy loam in texture, low OM, total N and available P. The CEC was low as well as exchangeable cations of K, Mg and Ca with Na being moderately low. The pH of the experimental site was moderately acidic.

Table 1 Initial soil properties

Particle Size Analysis		Value
Sand	(%)	83.98
Silt	(%)	5.62
Clay	(%)	10.40
Ph		5.90
EC	ds/m	0.051
Organic Matter	(%)	3.90
Total N	(%)	0.10
Avail P	($Mgkg^{-1}$)	2.49
Exchangeable Bases:		
Calcium	$Cmolkg^{-1}$	8.0

Magnesium	Cmolkg^{-1}	2.72
Sodium	Cmolkg^{-1}	0.08
Potassium	Cmolkg^{-1}	0.21
Exchange Acidity	Cmolkg^{-1}	2.6
Effective cation exchange capacity	Cmolkg^{-1}	13.61
B. Saturation	(%)	80.89

Nutrients composition of compost and compost materials. Table 2. The poultry droppings contained 2.41% nitrogen, 2.23 phosphorus and potassium 3.21. The organic carbon was 9.14% with a C:N ratio of 3.79. The cocoa pod husk (CPH) contained N.1.13%, P. 1.4%, K. 31.45% and Organic C 20.8% having a C.N. ratio of 18.4. The rice mill wastes nutrient content was 0.094%N, 0.92%P, 0.38% K and 27.6% OC with a C/N ratio of 29.36.

After composting, the cocoa pod husk amended with poultry dropping contained nutrients as 2.10% N, 0.92% P, 1.23% K and Org. C of 2.10%. The Rice mill waste (RMW) poultry amended compost has 1.22% N, 0.58% P, 0.95% K and org. C of 3.11% The C/N ratio of poultry manure makes it a suitable organic waste that can provide short term nutrients release in soils upon incorporation. Its nutrient composition of NPK is in conformity with the assertion stated that poultry droppings generally has the highest nutrients content among all animal feacal wastes [11]. The high C/N ratio of cocoa pod husk and Rice mill wastes were above the critical limits for normal degradation of < 16 as stated by [19], justifying the amendment of these organic materials with poultry droppings.

Table 2: Nutrient Composition of Compost Materials and Compost.

Compost materials	N gkg^{-1}	P gkg^{-1}	K gkg^{-1}	Org.C gkg^{-1}
Poultry Dropping PD	2.41	2.23	3.21	9.41
Cocoa Pod husk (CPH)	1.13	1.14	31.45	20.8
Rice mill waste (RMW)	0.94	0.92	0.38	27.6
Compost				
C P H +P D	2.10	0.92	1.23	2.10
R M W+P D	1.22	0.58	0.95	3.11

PD = poultry droppings, C P H = cocoa pod husk, RMW = rice mill waste.

Effect of poultry droppings amended cocoa pod and rice mill wastes compost on post cropping soil chemical properties.

The application of amended cocoa pod and Rice mill wastes (Tables 3, 4) indicated that all the compost rates at 2.5 – 10 t ha^{-1} increased the soil pH in the range of 6.10 – 6.22 in 2019 and 6.12 – 6. 55 in 2020.

The pH of the absolute control soils was 5.82 and 5.88 in 2019 and 2020 respectively while that of the inorganic fertilizer was 6.04 and 6.01 in 2019 and 2020, respectively. The organic matter of the post cropping soils with the compost ranged from 1.62 - 1.95% with composted cocoa pod husk (CCPH) amended with poultry droppings producing the highest amount for 2019 and OM content of 2020 ranged from 1.61 - 1.96% with poultry amended composted rice mill waste (CRMW) producing the highest value (1.96%). The control and inorganic NPK fertilizer has values of 1.30 and 1.21%,, respectively in 2019 and 1.28% and 1.30% respectively in 2020. Total N for the two types of compost at all rates increased ranging from 0.09 – 0.23% in 2019 and 0.10 – 0.24 in 2020. The inorganic fertilizer values were 0.10% in 2019 and 0.14% in 2020 while the zero manure control values were 0.07% in 2019 and 0.14% 2020. Available P for all compost treated soils ranged from

17.91 – 28.46 Mgkg-1 in 2019 and 18.13 - 29.40 Mgkg^{-1} in 2020. The inorganic values were 15.94 Mgkg^{-1} and 14.12 Mgkg^{-1} for 2019 and 2020, respectively while the zero control was 8.84 Mgkg-1 and 7.97 Mgkg-1 for 2019 and 2020, respectively.

Exchangeable K and Ca were increased by the two compost types at all rates. In the compost applied soils exchange K values ranged from 0.51 – 0.82cmolkg^{-1} and 0.51-0.82cmolkg^{-1} for 2019 and 2020 respectively while exchangeable Ca for the compost treated soils ranged from 3.41 – 4.52cmolkg^{-1} in 2019 and 3.38 – 4.80 cmolkg^{-1} in 2020 with the least values in the zero control soils (1.83 cmol/kg and 1.79 cmol/kg) in 2019 and 2020, respectively. The exchangeable acidity (EA) were reduced from the initial 0.13 before compost application to values ranging from 0.11 – 0.10 in all compost treated soils. The manures increased the ECEC from 2.75 in the control to value ranging from from 4.54 - 5.97cmol/kg in 2019 and from 2.60 cmolkg^{-1} in the control to values that ranged from 4.60 – 6.61 cmolkg^{-1} in 2020. The improvement in soil chemical properties observed in this study is a proof of the efficacy of organic wastes as a source of plant nutrients. The increase in soil pH by all compost types in the two years indicated that the compost amendments were effective in reducing soil acidity and the release of basic cations especially Ca as earlier noted by [20, 21]. The high OM content of the post cropping soils applied with the amended compost particularly at higher rates as organic residues and waste have been well documented [22, 23, 24]. This OM status of soils in this study was also supported by the assertion of [25] who noted that incorporation of organic fertilizer could be an efficient way of maintaining desired OM in soil. The lower level of OM in the inorganic fertilizer treatments in this study can be attributed singly to inorganic N, P and K in the fertilizer. This state of OM was observed and recorded highest decrease in OM from soil treated with inorganic fertilizers [26]. The increase in available P could be attributed to desorption of phosphate by inorganic inputs thus improving P availability. The increase in the content of exchangeable cations and reduction in exchangeable acidity due to amended compost of this study corroborate the findings as observed positive effects of organic amendments on soil chemical properties [27, 28, 29, 6].

Table 3: Effect of PD amended CPH and RMW on Post Cropping Soil Chemical Properties

Treatment	Rate(tha^{-1})	pH(H$_2$O)	OM (%)	Total N %	Av. P Mgkg^{-1}
2019					
Control	0	5.82	1.30	0.07	8.84
CCPH	2.5	6.10	1.62	0,09	17.91
CCPH	5.0	6.11	1.84	0.18	22.14
CCPH	7.5	6.20	1.82	0.23	24.32
CCPH	10	6.18	1.95	0.22	28.46
CRMW	2.5	6.11	1.68	0.16	18.41
CRMW	5.0	6.22	1.70	0.18	21.92
CRMW	7.5	6.21	1.76	0.21	28.10
CRMW	10	6.22	1.89	0.21	27.91
NPK	300kg ha^{-1}	6.04	1.21	0.10	15.94
2020					
Control	0	5.88	1.28	0.07	7.97
CCPH	2.5	6.12	1.61	0.10	18.13
CCPH	5.0	6.23	1.78	0.19	24.13
CCPH	7.5	6.40	1.91	0.20	26.91
CCPH	10.0	6.41	1.90	0.21	29.40
CRMW	2.5	6.21	1.67	0.12	19.15
CRMW	5.0	6.28	1.75	0.20	24.34
CRMW	7.5	6.55	1.96	0.21	27.95

CRMW	10.0	6.54	1.94	0.24	28.41
NPK 20.10.10	300kg ha^{-1}	6.10	1.30	0.14	14.12

CCPH = composted cocoa pod husk, CRMW = composted rice mill waste

Table 4: Post Cropping Soils Exchangeable cations as Influenced by PD amended CPH and RMW Compost.

Treatment	Rate	K	Ca	Mg	EA	ECEC
	($t\ ha^{-1}$)	----------- $Cmolkg^{-1}$ --------------				
2019						
Control	0	0.43	1.83	0.36	0.13	2.75
CCPH	2.5	0.51	3.41	0.51	0.11	4.54
CCPH	5.0	0.68	3.58	0.69	0.11	5.06
CCPH	7.5	0.62	4.52	0.64	0.10	5.88
CCPH	10	0.82	4.51	0.83	0.11	6.27
CRMW	2.5	0.64	3.34	0.49	0.10	4.57
CRMW	5.0	0.69	3.61	0.61	0.11	5.02
CRMW	7.5	0.78	4.18	0.91	0.10	5.97
CRMW	10	0.71	4.21	0.88	0.10	5.90
NPK	300kg ha^{-1}	0.49	2.41	0.51	0.12	3.53
2020						
Control	0	0.40	1.79	0.29	0.12	2.60
CCPH	2.5	0.51	3.38	0.60	0.11	4.60
CCPH	5.0	0.55	3.62	0.72	0.11	5.00
CCPH	7.5	0.77	4.80	0.89	0.10	6.56
CCPH	10	0.82	4.79	0.90	0.10	6.61
CRMW	2.5	0.61	3.49	0.70	0.11	4.91
CRMW	5.0	0.67	3.83	0.88	0.11	5.49
CRMW	7.5	0.79	4.64	0.01	0.10	6.54
CRMW	10	0.77	4.62	0.98	0.11	6.48
NPK 20.10.10	300kg ha^{-1}	0.50	2.18	0.50	0.12	3.30

CCPH = composted cocoa pod husk, CRMW = composted rice mill waste

Effects of Poultry droppings amended Cocoa pod and Rice mill waste Compost on Yield and Yield Components of Maize.

The yield and yield components of maize as influenced by poultry droppings amended cocoa pod husk and rice mill wastes (Table 5) indicated that the compost significantly increased the yield of maize over the control (O t ha^{-1}) manure and the inorganic fertilizer (NPK 20.10.10) treatment. Poultry droppings amended cocoa pod husk (CCPH) at the rate of 7.5 and 10 t ha^{-1} produced highest plant dry matter, highest number of seeds per cob and highest grain yield per unit area in 2019 (Table 5) 8.21gplant^{-1}, 368 seeds per cob and 3.89 t ha^{-1}, respectively for dry matter, number of seeds per cob and grain yield per unit area for 7.5 t ha^{-1} CCPH. The result followed same trend in 2020 as the same treatment produced highest values of these parameters. This was followed by poultry dropping amended rice mill waste (CRMW) applied at the rate of 7.5 t ha^{-1}. Inorganic NPK 10.10.10 at 300 kg ha^{-1} was ranked third while the least yield of 5.96 gplant^{-1}, 218 seeds per cob and 0.38 t ha^{-1} grain yield, respectively of dry matter, number of seeds per cob and grain yield per unit area in 2019 and 5.78g/plant, 198 seeds per cob and 0.42 t ha^{-1} grain yield per unit area for 2020 was obtained from the absolute control.

The yield response of maize to the application of the poultry droppings amended compost of cocoa pod husk and rice mill waste can be attributed to the ease of decomposition and mineralization of the amended organic materials which could have otherwise immobilized N and other nutrient due to their low C/N ratios. The improvement in the soil chemical properties in this study of increased pH, total N, available P, and increased exchangeable cations and ECEC in the post cropping soils is an indication that the maize plants had a suitable soil environment with adequate nutrients levels during the growing cycle. This is in agreement with the assertion of [4] that nutrients contained in organic manures are released more slowly and are stored for a longer time in soil thus supporting better crop growth, development and ultimately increase yields. The blending of organic materials to reduce the inhibitive properties of decomposition and subsequent mineralization of some organic wastes to meet crops immediate needs have been reported: [5] used poultry droppings and cow dung; [6] blended moringa leaf and poultry droppings which improved soil properties and increased yield of garden egg [30] added animal dung to cocoa pod husk, which boosted and hastens rate of decomposition, while [31] used cocoa pod compost with poultry droppings, which produced highest yield and tallest maize plants over the inorganic NPK fertilizer. Similarly, [32] reported the combination of cocoa pod ash and poultry droppings that increased maize growth, yield and yield components. In other compost amendment studies,[33] observed a 30% N replacement by compost as an effective nutrient management strategy to maintain N uptake and yield of maize, while [34] reported that, increasing compost up to 10 tha^{-1} increased maize yield, its components and protein content. Similarly, [35] found that compost application produced more maize ears per unit area and grain yield of 65 % over the control.

Table 5: Yield and Yield Component of Maize Influence by PD amended Cocoa pod husk and Rice mill wastes

Treatment	Rate t ha^{-1}	2019			2020		
		Dry matter g/plant	No. of seed cob^{-1}	Grain yield t ha^{-1}	Dry matter gplant-1	no of seed cob^{-1}	Grain yield t ha^{-1}
Control	0	5.96e	218e	0.38f	5.78d	198e	0.42f
CCPH	2.5	6.88d	295d	1.80e	6.79c	260d	1.88de
CCPH	5.0	7.62c	340c	2.92d	7.56ab	330d	2.98c
CCPH	7.5	8.21a	368a	3.92a	8.10a	359a	3.89a
CCPH	10.0	8.10a	370a	3.81a	8.82	364a	3.83ab
CRMW	2.5	6.52e	289de	1.48e	6.60cd	261d	1.60e
CRMW	5.0	7.22cd	300d	2.61	7.18bc	296c	2.88d
CRMW	7.5	7.95b	358b	3.78ab	7.55ab	351ab	3.80ab
CRMW	10.0	7.98b	365ab	3.80ab	7.90ab	356ab	3.79ab
NPK	300kg ha^{-1}	7.40c	342c	3.45c	7.41b	329b	3.47bc
	Mean	7.38	324.5	2.80	7.29	310	2.87
	SE±	0.11	3.0	0.04	0.09	6.1	0.07

Values followed by different lower case letters are significantly different at $P<0.05$ using Duncan's Multiple Rage Test (DMRT).

Conclusion

The application of poultry droppings amended cocoa pod husk and rice mill waste compost effectively improved soil chemical properties as well as yield of maize over the inorganic fertilizer and the control. The application of the amended compost of cocoa pod husk and rice mill waste at all rates improved soil pH, OM, N, P, exch. K, Ca and ECEC and reduced the Exchangeable Acidity. Application of cocoa pod husk amended with poultry droppings at the rate of 7.5 t ha^{-1} produced highest plant dry matter, number of seeds per cob and highest grain yield per unit area consistently for the two years. This compost therefore is suitable for optimum maize yield and improvement of soil chemical properties. This organic amendment therefore can substitute the costly and scarce inorganic fertilizer which has been a serious limitation to increased crop yields by the poor resource farmers that dominate the Nigeria agricultural land scape. However, a revalidation of the findings of this study across the different agro-ecological zones of Nigeria will provide a basis for a valid recommendation to address the fragile nature of our tropical soils vis-à-vis Nigeria food security crises.

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AUTHORS' CONTRIBUTIONS

This research idea was conceived, designed and laid out in the field by me (the author). The experimental materials were sought and procured as well as the literature by the author.

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