

Soil Fertility Status of Cassava Fields in South Western Nigeria

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ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Aims: Information on nutrient status of soils of south western Nigeria needed in developing appropriate integrated nutrient management packages for cassava production is lacking. This study is designed to provide information on fertility status of some soils of the area and identify constraints to cassava production.

Study design: A field survey.

Place and Duration of Study: The study was carried out in March 2009 within two agro ecological zones of Osun state, south western Nigeria.

Methodology: A field survey of 33 farmers' fields in two agro ecological zones of Osun state namely; Iwo zone and Oshogbo zone was undertaken. Representative soil samples (0-20cm) were obtained from each field. Physical and chemical properties of soil samples were determined in the laboratory following established methods. Statistical analysis of soil data was carried out also.

Results: The soils of the area are acidic (pH in water range: 5.4 -6.4) and 79% of the fields are deficient in soil organic matter. Nitrogen and phosphorus are below established critical limits for cassava production in half of the fields; exchangeable cations (calcium, magnesium and potassium) are present in adequate amounts in most soils. No significant differences (P .05) were between the zones observed for soil properties measured.

Conclusion: Farmer acceptable strategies for improving soil organic matter and overall soil health through use of fertilizers, organic materials, multipurpose legumes among other options are required for sustained cassava production.

Keywords: [Nitrogen, phosphorus, mehlich soil test, micro nutrients, fertilizer, organic material]

1. INTRODUCTION

Cassava (*Manihot esculenta*) is an important staple crop for more than 700 million people in the developing world, about 500 million of whom reside in Africa (FAO, 2003; El-Sharkawy, 2004). The majority of production is in Africa and Nigeria ranks as the largest producer of cassava worldwide, harvesting over 35 million tonnes of fresh roots from 3.1 million hectare of land (FAO, 2011).

Cassava production in Nigeria is mainly in the hands of small scale farmers under rain fed conditions. The crop plays a vital role in the food security of the rural economy of Nigerians because of its ability to tolerate drought and give reasonable yield in soils of low fertility (Ezedinma et al. 2006), hence the name 'poor man's crop'. Therefore, cassava is most often grown in marginal soils and comes last in a crop rotation cycle (Nweke et al. 2002; Adjei-Nsiah et al. 2004).. Population pressure on land has resulted in reduced fallow periods, more intensive use of land and increasing problems of soil infertility. In addition, fertilizer is scarce and priced much higher than the average farmer can afford thereby effectively limiting its use

in cassava cultivation (FAO, 2005). Constant depletion and little or no external addition of plant nutrients impoverish the soil, resulting in declining yields and soil degradation. Average farm yield of cassava in Nigeria is lower (10.8 t ha^{-1}) compared to India ($> 27 \text{ t ha}^{-1}$) (FAO, 2011). In East Africa, using integrated management practices increased average yields of cassava up to 20 t ha^{-1} on farmers' fields and 60% of the increase was attributed to fertilizer use (Fermont, 2009). Therefore, soil fertility is a major constraint in cassava production (Spittel and Van Huis, 2000) and must be overcome if the Federal government of Nigeria backed "cassava initiative" for rural industrial development and economic empowerment will be realized.

An important step in achieving this is an inventory providing valuable information on the current fertility status of cassava growing soils and appropriate zonal specific soil nutrient management options. This study was designed to begin an assessment of the fertility status of soils under cassava in Osun state, Nigeria.

2. MATERIAL AND METHODS

2.1 Study Site

Osun state (7.5000° N , 4.5000° E) in south western Nigeria has a tropical climate with distinct wet and dry seasons. It is characterized by a bimodal rainfall pattern and 7- 8 months of rainfall, permitting the cultivation of long growing crops like cassava in a predominantly rain fed system. The mean annual temperature varies between 21°C and 31°C and annual rainfall ranges between 800 mm in the Savannah agro-ecology to 1,500 mm in the rain forest belt.

Cassava is an important crop occupying 69, 353 ha of land or 45% of the total land area cultivated in the state (Osun state government, 2012). The state is divided into three agricultural zones based on its agro-ecological and cultural characteristics namely; Iwo, Oshogbo and Ife/Ijesha. Although cassava is grown in all three zones, it is relatively less important in Ife/Ijesha zone where tree based farming of cocoa (*Theobroma cacao*) and kola nut (*Cola nitida*) mainly predominates. Arable crop farming is predominant in the other two zones and cassava is an important component in cropping systems. Therefore, Iwo and Oshogbo zones were selected for the survey. A brief description of each of the zones studied is given as follows:

Iwo zone (Forest/savannah transition)

This zone is characterized by derived savanna vegetation with rainfall averaging 1100mm/annum. The soils of the area are mainly derived from undifferentiated basement complex rocks with pebble beds and to a lesser extent coarse granite parent material. Arable crops cultivated include maize (*Zea mays*), cassava, okra (*Hibiscus esculentus*) and chilli pepper (*Capsicum* sp.). The topography is mainly undulating plains, dissected plains and patches of nearly level to gently undulating plains.

Oshogbo zone (Savanna zone)

This zone is comprised of land described as gently undulating plains with undulating dissected plains. Annual rainfall is about 800mm per annum. The soils of the area are derived mainly from quartzite and basement complex rocks. The main crops cultivated are maize, cassava, okra, and cowpea (*Vigna unguiculata*).

2.2 Soil Sampling and Laboratory Analyses

Cassava is a major crop grown for food and cash in both zones. In most of the sites selected for soil sampling, cassava was grown as a sole crop. On a few sites, it was intercropped with maize, okra or chilli peppers. The location of the sites was arrived at in conjunction with the state agricultural development program (ADP) personnel. A host of factors were considered namely; cassava production potentials of the locations, accessibility by road and approximate distribution of soil types. A total of 33 sites were sampled. The survey was carried out in March 2009.

Soil samples were taken from fields in the following manner. Four cores were randomly sampled using a soil auger at 0-20 cm soil depth, and bulked to form a composite. The composites were air dried and ground to pass through a 2 mm sieve.

The soil samples were analyzed for texture (Bouyoucos, 1962), pH in water (1:1) and KCl (1:1). Total N was determined by the Micro-Kjeldahl method (Jackson, 1962) and available P was by Bray's P1 method (Bray and Kurtz, 1945). Exchangeable bases (K, Ca and Mg) and micronutrients (Cu and Zn) were extracted with Mehlich-3 solution (Mehlich, 1984). The ratio of soil to extraction solution used was 1:10.

The exchangeable acidity was determined by extracting 2g of soil with 20 ml of the extract with 0.01N NaOH using phenolphthalein indicator. Organic carbon (C) was determined using wet Walkey Black dichromate digestion method (Nelson and Sommers, 1982). Organic matter (OM) was derived from data on organic C as follows:

OM = Organic C*1.7

2.3 Statistical Analysis and Data Presentation

Descriptive statistics (mean, median, minimum and maximum values) of soil physical and chemical characteristics are presented. One way analysis of variance by soil zone was carried out on measured soil properties. Correlation and regression analyses were performed on the soil data. All computations were carried out using Microsoft Excel.

3. RESULTS AND DISCUSSION

Soil pH in water varied among sites from 5.4 to 6.4 with a coefficient of variation of 4.3% (Table 1). The soils were moderately to slightly acidic. Cassava is tolerant of soil acidity (Howeler, 2002) and so acidity would not severely constrain production since all of the soils were within adequate levels of pH for cassava production (Table 2).

Two key inter-related properties to be considered in soil fertility maintenance and build up are the soil organic matter and soil organic carbon (SOC). Soil organic carbon is the major component of soil organic matter. Depleting SOC threatens soil productivity since it plays a vital role in plant nutrient supply, determines response to N and P fertilizer enhances cation exchange capacity and improves soil physical structure and processes (references). Tropical soils have typically low levels of SOC, < 20 to 30 g kg⁻¹ (Bationo et al. 2007). In this study, the SOC of all soils ranged between 4.4 and 26.6 (Table 1) and 86% of the soils had SOC less than 20 g kg⁻¹. Soil organic matter ranged from 0.7% to 4.5% and 14% of the soil samples had organic matter above 4%. For a critical level of 3.0 % organic matter for crop production in Nigeria (Akinrinde and Obigbesan, 2000), 79% of the soils had low levels of organic matter (equally distributed among both zones) and a fifth of the soils (21%) had > 3.0 % organic matter.

122 Total N values of the soils ranged from 0.45 g kg⁻¹ to 2.76 g kg⁻¹. Total N content in fifty
 123 percent of the soils was lower than the critical value of 0.15% (Agboola and Corey, 1973),
 124 obtained for maize in some southwestern Nigerian soils. Linear regression analysis showed
 125 that a difference of 1 g kg⁻¹ in organic matter resulted in a difference of 0.49 g kg⁻¹ in total N
 126 (standard error = 0.066; r = 0.90). Building up the soil organic matter levels is a key to
 127 increasing soil N content and largely determines the fertility of soils of the tropics (Buresh
 128 and Giller, 1998; Yao et al. 2010).

129 Phosphorus extracted by Bray's P 1 solution varied widely, and ranged from 0.12 to 39.95
 130 mg P kg⁻¹ soil. Fifty percent of the soil samples were above the critical level for cassava
 131 production (8 mg kg⁻¹ P from Table 2). This is much lower than the critical soil P levels
 132 determined for most other crops; cassava is able to grow at relatively low P levels because
 133 of symbiosis with mycorrhiza fungi in the root surface that improves the plant's P nutrition
 134 (Howeler, 1990).

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136 **Table 1. Properties of soils from Iwo and Oshogbo zones of Osun state, Nigeria**
 137 **(results combined and presented by zone), 2009.**

Soil property	Measure of average	All soil samples	Iwo soils	Oshogbo soils
pH (water)	Mean	5.9	5.7	6.0
	Median	5.8	5.8	5.9
pH (KCl)	Mean	5.4	5.5	5.5
	Median	5.4	5.3	5.4
Organic carbon g kg ⁻¹	Mean	14.9	14.3	15.5
	Median	14.5	12.7	16.0
Organic matter (%)	Mean	2.5	2.4	2.6
	Median	2.5	2.2	2.7
Nitrogen g kg ⁻¹	Mean	1.47	1.34	1.60
	Median	1.48	1.32	1.66
Phosphorus mg kg ⁻¹	Mean	12.19	10.51	13.87
	Median	7.24	5.67	8.80
Exch. Acidity	Mean	0.43	0.42	0.43
	Median	0.40	0.40	0.40
Calcium cmol _c kg ⁻¹	Mean	2.59	2.86	2.32
	Median	1.54	1.21	2.68
Magnesium cmol _c kg ⁻¹	Mean	1.50	1.32	1.67
	Median	1.16	1.26	1.06

Potassium $\text{cmol}_c \text{ kg}^{-1}$	Mean	0.38	0.31	0.44
	Median	0.36	0.32	0.38
Copper mg kg^{-1}	Mean	2.03	1.92	2.14
	Median	2.13	1.88	2.14
Zinc mg kg^{-1}	Mean	6.45	5.39	7.51
	Median	6.57	3.24	6.80
Particle size g kg^{-1}				
Sand	Mean	826	823	828
	Median	826	846	826
Silt	Mean	129	131	128
	Median	134	114	134
Clay	Mean	45	46	44
	Median	40	40	40

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152 **Table 2. Approximate soil fertility indices according to nutrient requirements for**
 153 **cassava and maize**

Soil property	Method	Medium/critical level(range)	Country	Source
pH H ₂ O	(1:1)	4.6-7.8		CIAT (1979)
Organic matter		3%	Nigeria	Akinrinde and Obigbesan (2000)
P	Bray 1	8 mg kg ⁻¹	Nigeria	Kang et al. 1980
Ca*	Mehlich-3	0.3 cmol _c kg ⁻¹	Malawi	Wendt, 1995
Mg*	Mehlich-3	0.6 cmol _c kg ⁻¹	Malawi	Wendt, 1995
K	Mehlich-3	0.2 cmol _c kg ⁻¹	Malawi	Snapp, 1998
Zn	Mehlich-3	1.0 mg kg ⁻¹	Malawi	Wendt, 1995
Cu	Mehlich-3	0.5 mg kg ⁻¹	Malawi	Wendt, 1995

154 *Values for Ca and Mg divided by 200 and 120 respectively to convert from mg dm⁻¹ to cmol_c kg⁻¹.*

155 The Mehlich-3 (M-3) soil extractant was used in cations and micronutrients determination. It
 156 is an efficient method for soil nutrient determination, especially in acid and neutral soils,
 157 since it can simultaneously extract multiple nutrients, saving time and money. The test
 158 method has been considerably researched with different crops and calibrated with other soils
 159 test methods, so that there is considerable information in literature (Hylkema, 2011).
 160 However, there exists no soil test calibration or interpretation for cassava, therefore general
 161 soil test calibration and interpretations for maize were used.

162 The mean of extractable K was 0.38 when data for both zones were combined, 0.31 for Iwo
 163 zone and 0.44 for Oshogbo zone (Table 1). The minimum and maximum values were 0.18
 164 and 0.69 cmol_c K kg⁻¹ respectively. Using a tentative M-3 K critical value of 0.2 cmol_c kg⁻¹ for
 165 upland soils of Malawi (Table 2), K was at adequate levels in most of the soils. Some
 166 locations in Oshogbo had relatively higher K values and this might be due to the particular
 167 parent materials from which these soils were derived since these locations do not have a
 168 history of better fertilizer applications than the other locations in this study (Sangoyomi and
 169 Ayandiji, unpublished data). Extractable Ca varied widely, and the range was from 0.73 to
 170 7.23 cmol_c kg⁻¹. Although median and mean values for Iwo and Oshogbo soils differed
 171 substantially, all soils had greater than the critical limit proposed for extractable Ca (Tables 1
 172 and 2).

173 Extractable Mg had a median of 1.16 and ranged from 0.53 to 4.05 cmol_c kg⁻¹, with higher
 174 mean values in Oshogbo (Table 1). Magnesium appears to be sufficient throughout most of
 175 the study area, as 93% of the soils had Mg values above the proposed critical level of 0.6

176 $\text{cmol}_c \text{ kg}^{-1}$ (Table 2). The study however reveals isolated areas of Mg deficiency. Response
 177 of cassava to Mg application in acid soils of southern Nigeria has been reported (Kang,
 178 1984).

179 Studies on soil micronutrients levels for crop production are less commonly reported in
 180 literature. Tentative soil Zn and Cu critical values for maize production in upland soils of
 181 Malawi have been proposed (Wendt, 1995). Zinc in soil ranged from 2.88 mg kg^{-1} to 11.04
 182 mg kg^{-1} ; mean and median values were higher for Oshogbo than for Iwo zone (Table 1). Soil
 183 Zn was adequate in all soils (Table 2). Using general soil values proposed by Adepetu, and
 184 Sobulo and Adepetu as cited in FAO (2000), soils with Zinc level greater than 3 mg kg^{-1} are
 185 high, and 93% of all soils sampled belong in this category. Soil Zn showed significant
 186 positive correlations with soil pH and extractable cations, correlation with exchangeable
 187 acidity was negative but not significant at $P = .05$ (Table 3).

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189 **Table 3. Correlations of zinc and copper with selected soil properties**

Property	Zn	Cu
pH (H_2O)	0.62*	0.28 ^{ns}
pH (KCl)	0.72**	0.63*
Exch. Acid	-0.44 ^{ns}	-0.75**
Ca	0.65**	0.49 ^{ns}
Mg	0.60*	0.43 ^{ns}
K	0.57*	0.46 ^{ns}

190 Note: ^{ns}, * and ** denote not significant ($P < 0.05$), significant at ($P < 0.05$) and ($P < 0.01$) levels of
 191 significance, respectively.

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193 The median level of Cu was 2.03 mg kg^{-1} overall, and median levels of 1.92 mg kg^{-1} and
 194 2.14 mg kg^{-1} were recorded for Iwo and Oshogbo zones respectively (Table 1). Soil Cu
 195 ranged from 1.16 mg kg^{-1} to 2.83 mg kg^{-1} . Table 3 presents correlation results of Cu with
 196 some soil properties. Copper content of soil significantly correlated with exchangeable
 197 acidity and pH (KCl), but not with pH (H_2O). The variation in soil Cu attributable to the two
 198 variables was 67% in both zones. The regression equation was $\{\text{Cu} = -0.33 + (0.72 \cdot \text{pHKCl X}) +$
 199 $(-3.5 \cdot \text{Exch. Acid X})\}$. All the soils appear to have adequate levels of Cu in them.

200 Sand was the dominant particle fraction, comprising between 75 and 91% of total soil
 201 particle fraction. Mean values for sand in Iwo and Oshogbo were similar (Table 1). These
 202 results are typical of soils within this region generally described as sandy in texture and well
 203 drained (Salako et al. 1999). From soil texture analysis, most of the soils fall into the sandy
 204 loam class, with few exceptions; a lone field from Iwo zone classified as sand and another
 205 one from Oshogbo zone classified as loamy sand. Sand, silt and clay fractions had median
 206 values of 826 g kg^{-1} , 134 g kg^{-1} and 40 g kg^{-1} respectively. All soils consisted of less than

10% clay by proportion. The clay type often encountered is the kaolinite, which is of the low activity type. The silt/clay ratio of the soils was low and ranged between 0.8 and 5.4, an indication of the high degree of weathering that had occurred in the soils. These coarse textured soils have low plant available water holding capacity due to their low specific surface area (Reichert et al., 2010). The rate of nutrient leaching from applied fertilizer in these soils would also be quite high.

Statistical analysis of soil properties by analysis of variance (ANOVA) indicated that there were no significant differences at $P = .05$ between the two zones. However, Iwo zone was generally characterized by more acidic soil conditions, with low total N, available P and exchangeable K. Micronutrients levels (Cu and Zn) in the soils of this zone were relatively lower than for Oshogbo zone. Soils within Oshogbo zone seemed relatively more fertile than Iwo zone, with higher pH values, more organic matter, available P and total N in the top soil. The soils of this zone also had higher exchangeable bases. The soils of both zones are high in sand and are predominantly of the sandy loam class.

The “cassava initiative” program has the mandate to transform the crop from its humble position as a famine-security crop to an industrial crop for rural empowerment and foreign exchange generation. This entails developing efficient and stable production and marketing channels to serve both domestic industries and export markets.

As high yielding cassava cultivars are increasingly adopted by farmers, nutrient mining accelerates and multiple nutrient deficiencies become increasingly common. Fermont et al. 2007 observed that when cassava tuber yield increased from 10 t ha⁻¹ obtained using farmer traditional varieties to 30 t ha⁻¹ with improved varieties, amounts of N, P and K removed per hectare tripled thereby aggravating the rapid depletion of soil nutrient stocks.

The International Institute of Tropical Agriculture (IITA), Nigeria, recommends application of any of the following fertilizers on a one hectare cassava farm: (1) NPK 15:15:15– 12 bags of 50 kg each; NPK 20:10:10– 9 bags of 50 kg each and NPK 12:12:17–15 bags of 50 kg each. This translates to about a fifth of the production cost (minus fixed expenditure) incurred on the farm for a projected yield of at least 25 t ha⁻¹ (IITA, 2005). In reality farmers hardly apply fertilizer to cassava (Nweke, 1994). Fertilizer procurement in Nigeria is plagued by a host of problems including poor distribution channels, inadequate supply and high cost. In addition, farmers are often unwilling to take the risk of incurring added cost from fertilizer which might not translate to monetary profit. Any of a combination of different factors such as time and number of weeding, pests and disease incidence, variety used and weather conditions (especially rainfall) could affect cassava yield. Agbaje and Akinlosotu (2004) observed that fertilizer application did not increase cassava tuber yield in seasons with excessive or inadequate rainfall at the active growth stage.

Since fertilizer use in cassava production is minimal at the moment, flexible approaches to fertilizer use must be developed. A blanket fertilizer recommendation often fails to take into consideration differences in resource endowment (soil type, labor capacity, climate risk) nor make allowances for dramatic changes in input/output price ration (Bationo et al. 2006), thereby deterring farmers from fertilizer application. Among cereal farmers in dry regions of West Africa, a method of applying small amounts (micro-dose) of fertilizer strategically to individual planting stations has been adopted. Fertilizer used is a third of the recommended rates and yield increased by 43% than with the earlier recommended fertilizer broadcasting methods (Tabo et al. 2006). Bationo and Bukert (2001) explained that small amounts of fertilizers are more affordable to farmers, give an economically optimum result and increase nutrient uptake efficiency. The place of micro-dosing in cassava production might be assessed.

Combined use of inorganic and organic fertilizers for sustainable cassava production warrants being examined. Results from preliminary trials such as Ayoola and Makinde

(2007) suggest that yield from organic and inorganic fertilizer combinations would not be inferior to sole inorganic fertilizer. Organic technologies that evaluate presently discarded crop residues, industrial wastes and other readily available organic materials together with mineral fertilizers for soil replenishment in cassava production are needed. Of particular interest and potential benefits are studies that focus on improving fertilizer use efficiency in organic and inorganic fertilizer combinations, soil N and P replenishment and building up the soil organic carbon stock through proper crop residue management. The potential contributions of legumes introduced (as relay, inter crop or rotation) in cassava systems and N fertilizer saving should be addressed. Quick growing legume planted fallows are options to be exploited. An added benefit of organic materials addition is that in sufficient amounts, it acts much like lime to reduce soil acidity and enhance nutrient availability in acid soils (Lal, 1981). Farmers within the study area rarely apply lime to their soils although it is recommended (IITA, 2005).

For P, studies utilizing local phosphate rocks such as Ogun rock phosphate which is available in commercial quantities within south western Nigeria are needed. These studies would need to address cassava P use efficiency of phosphate rock compared with commercial phosphorus fertilizers.

In as much as a single set of recommendation would not do for the diverse agricultural environments and economic conditions that prevail within the study area, technologies that explore composite approaches need to be further developed with the farmer fully participating. Here, extension officers allow farmers access to appraise and choose appropriate and cost-effective technologies suitable for their unique circumstances (Snapp et al. 1998; Gruhn et al. 2000).

Chemical soil testing is completely alien to traditional agriculture, but must come into forefront in commercial cassava production as soil reserves become depleted. Traditional soil tests extract either one or a small group of nutrients, so that test for an extended range of nutrients requires multiple individual tests at high cost to farmers. However, the Mehlich-3 soil test provides a rapid and cost effective means of measuring up to 13 nutrients (B, Ca, Co, Cu, Fe, K, Mg, Mn, Mo, P, Na, S and Zn) simultaneously (Walton and Alle, 2004). The test would greatly reduce cost and simplify soil test procedures. Therefore, studies focused on calibrating the soils test for southern Nigeria soil types are needful.

4. CONCLUSION

Soils of Iwo and Oshogbo zones are mainly sandy loam and moderately to slightly acidic. The major soil constraints identified in this study are low organic matter, (which influences a host of soil physical, chemical and biological attributes including available nitrogen supply, cation exchange capacity and fertilizer use efficiency) and phosphorus. Innovative strategies for reducing inorganic fertilizer use by combining with organic means of fertilization are required for farmers' appraisal. The set of technologies adopted by farmers would vary and represent the most appropriate and cost effective methods for each farm. Finally, recent results on soil test calibration interpretation for cassava in these zones are required

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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