Soil Fertility Status of Cassava Fields in South Western Nigeria

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ABSTRACT

Aims: Current information on nutrient status of south western Nigeria soils is needed to develop appropriate integrated nutrient management packages for sustainable cassava production within the area. This study is designed to provide information on fertility status of some soils of the area.
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 analyses of soil data was carried out using appropriate techniques.
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 observed between the zones for soil properties measured.
Conclusion: Farmer acceptable strategies for improving nutrients availability (particularly nitrogen and phosphorus), organic matter and overall soil health through use of fertilizers, organic materials and 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 land use and increasing problems of soil infertility (Rao and Mathuva, 2000). In

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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 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℃ and 31℃ and annual rainfall ranges from 800 mm in the Savannah agro-ecology to 1,500 mm in the rain forest belt. The population of the state was estimated at slightly below 3.5 million from the last population census in 2006. More than half the population of the state is directly or indirectly involved in farming.

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 (Figure 1). 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 1100 mm per 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. The topography is mainly undulating plains, dissected plains and patches of nearly level to gently undulating plains.

Farmlands may be acquired by inheritance, purchase, leasing etc. Typically, farm size ranges between 0.5-2 ha; farmers may have multiple farm plots (fragmented farm holdings). Land management options commonly practiced within the study area include the use of cover crops, multiple cropping, crop rotations, growing nitrogen fixing legumes and fallow. With shrinking land resource, fallow periods have become progressively shorter in length and farmlands are intensively cultivated for up to a decade or more before being allowed to fallow. Inorganic fertilizer use in Osun state is estimated at 11.3 kg ha^{-1} (Salimonou, 2008).

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Arable crops cultivated include maize (*Zea mays*), cassava, okra (*Hibiscus esculentus*) and chilli pepper (*Capsicum* sp.).

Oshogbo zone (Savanna zone)

This zone is located at the northern part of the state and it is characterized by savanna vegetation. The topography is mainly gently undulating plains with undulating dissected plains. Annual rainfall is about 800 mm per annum. Average farm size is between 0.5 and 1.5 ha, and farmlands are typically inherited, being passed on to succeeding generations. They may also be purchased outright or leased, payment being cash or a share of the farm produce.

Apart from the use of fertilizer, other soil fertility management options adopted within the area include crop rotation, intercropping legumes with other complementary crops, use of organic manures, mulching with organic residues and short duration bush fallows less than four (4) years in length. The soils of the area are derived mainly from quartzite and basement complex rocks. The main crops cultivated are maize, cassava, okra, soybean (*Glycine max*) and cowpea (*Vigna unguiculata*).

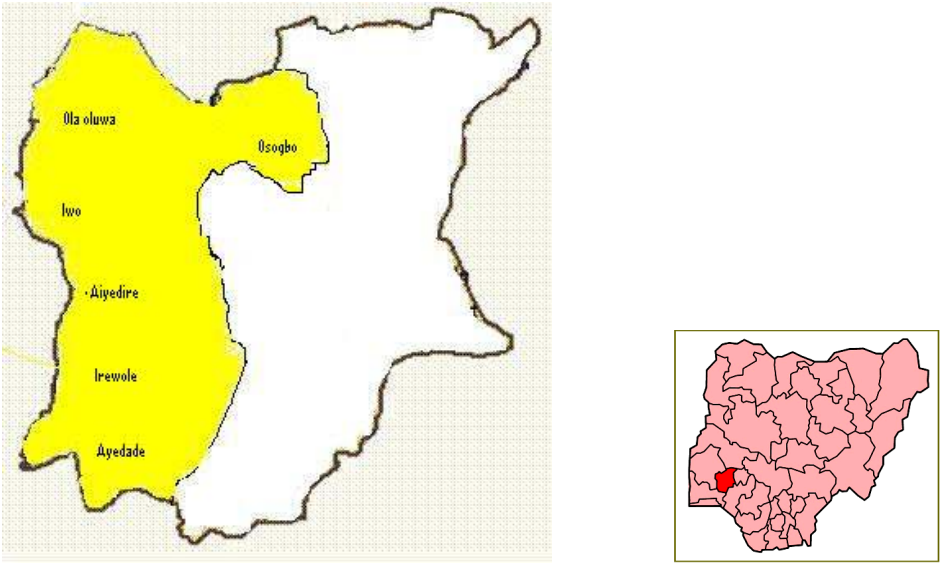

Figure 1. Map of Osun State, Nigeria with study area shaded. Inset is map of Nigeria with Osun state highlighted

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

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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 and determined by titration 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, minimum and maximum values) of soil physical and chemical properties 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

3.1 Acidity, Organic Matter and Macronutrients Status of Soils of Iwo and Oshogbo Zones

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). Organic matter improves soil chemical properties in three ways; as a net source of carbon and nutrients, increases cation exchange capacity and stimulates biological activity (Asadu et al., 1997). Soil organic carbon is the major component of soil organic matter and plays a vital role in plant nutrient supply, determines response to N and P fertilizer and improves soil physical structure and processes (Motavalli et al., 1994). Declining SOC indicates soil degradation with resulting decline in crop yields (Sanchez et al., 1997). 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%

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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.
Total N values of the soils ranged from 0.5 g kg^{-1} to 2.8 g kg^{-1}. Total N in fifty percent of the soils was lower than the critical value of 0.15% (Agboola and Corey, 1973), obtained for maize in some southwestern Nigerian soils. Linear regression analysis showed that a difference of 1 g kg^{-1} in organic matter resulted in a difference of 0.5 g kg^{-1} in total N (standard error = 0.066; r = 0.90). Building up the soil organic matter levels is a key to increasing soil N content and largely determines the fertility of soils of the tropics (Buresh and Giller, 1998; Yao et al. 2010).

Phosphorus extracted by Bray's P 1 solution varied widely, and ranged from 0.1 to 40.0 mg P kg^{-1} soil. Fifty percent of the soil samples were above the critical level for cassava production (8 mg kg^{-1} P from Table 2).

Table 1. Selected chemical properties of soils from Iwo and Oshogbo zones of Osun state, Nigeria (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
	Range	5.4-6.4		
pH (KCl)	Mean	5.4	5.5	5.5
	Range	5.0-5.8		
Organic carbon g kg^{-1}	Mean	14.9	14.3	15.5
	Range	4.4-26.7		
Organic matter (%)	Mean	2.5	2.4	2.6
	Range	0.7-4.5		
Nitrogen g kg^{-1}	Mean	1.5	1.4	1.6
	Range	0. 5-2.8		
Phosphorus mg kg^{-1}	Mean	12.2	10.5	13.9
	Range	0.1-40.0		
Exch. Acidity	Mean	0.4	0.4	0.4
	Range	0.3 -0.6		
Calcium $cmol_c$ kg^{-1}	Mean	2.6	2.9	2.3
	Range	0.7-7.2		
Magnesium $cmol_c$ kg^{-1}	Mean	1.5	1.3	1.7
	Range	0.5-4.1		

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Potassium $cmol_c\ kg^{-1}$	Mean	0.4	0.3	0.4
	Range	0.2-0.7		

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

Soil property	Method	Medium/critical level(range)	Country	Source
pH H_2O	(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

Values for Ca and Mg divided by 200 and 120 respectively to convert from mg dm^{-1} to $cmol_c\ kg^{-1}$.

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

The mean of extractable K was 0.4 $cmol_c\ kg^{-1}$ when data for both zones were combined, 0.3 $cmol_c\ kg^{-1}$ for Iwo zone and 0.4 $cmol_c\ kg^{-1}$ for Oshogbo zone (Table 1). Using a tentative M-3 K critical value of 0.2 $cmol_c\ kg^{-1}$ for upland soils of Malawi (Table 2), K was at adequate levels in most soils. Some locations in Oshogbo had relatively higher K values and this might be due to the particular parent materials from which these soils were derived since these locations do not have a history of better fertilizer applications than other study locations (Sangoyomi and Ayandiji, unpublished data). Extractable Ca varied widely, and the range was from 0.7 to 7.2 $cmol_c\ kg^{-1}$. Although mean values for Iwo and Oshogbo soils differed

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substantially, all soils had greater than the critical limit proposed for extractable Ca (Tables 1 and 2).

Extractable Mg ranged from 0.5 to 4.1 $cmol_c$ kg^{-1}, with higher mean values in Oshogbo (Table 1). Magnesium appears to be sufficient throughout most of the study area, as 93% of the soils had Mg values above the proposed critical level of 0.6 $cmol_c$ kg^{-1} (Table 2). The study however reveals isolated areas of Mg deficiency. Response of cassava to Mg application in acid soils of southern Nigeria has been reported (Kang, 1984).

3.2 Particle Size Analysis and Micronutrient Status of Soils from Iwo and Oshogbo Zones

Studies on soil micronutrients levels for crop production are less commonly reported in literature. Tentative soil Zn and Cu critical values for maize production in upland soils of Malawi have been proposed (Wendt, 1995). Zinc in soil ranged from 2.9 mg kg^{-1} to 11.0 mg kg^{-1} (Table 3). Using the M-3 test, Chude et al (2003) proposed a tentative soil Zn level of 1.29 mg kg^{-1}, above which soil Zn is adequate for maize production in Samaru, northern Nigeria, only slightly higher than was obtained for some soils of Malawi (Table 2). Zinc appears sufficient within the study area. Soil Zn showed significant positive correlations with soil pH and extractable cations at P =.05 (Table 4).

Table 3. Micronutrients (copper, zinc) and physical properties of soils from Iwo and Oshogbo zones of Osun state, Nigeria (results combined and presented by zone), 2009.

Soil property	Measure of average	All soil samples	Iwo soils	Oshogbo soils
Copper mg kg^{-1}	Mean	2.0	1.9	2.1
	Range	1.2-2.8		
Zinc mg kg^{-1}	Mean	6.5	5.4	7.5
	Range	2.9-11.0		
Particle size g kg^{-1}				
Sand	Mean	826	823	828
	Range	736-912		
Silt	Mean	129	131	128
	Range	40-214		
Clay	Mean	45	46	44
	Range	40-60		

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Table 4. 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}

*Note: ns, * and ** denote not significant (P <0.05), significant at (P <0.05) and (P <0.01) levels of significance, respectively.*

The mean value of Cu was 2.0 mg kg^{-1} overall, and mean values of 1.9 mg kg^{-1} and 2.1 mg kg^{-1} were recorded for Iwo and Oshogbo zones respectively (Table 1). Soil Cu ranged from 1.2 mg kg^{-1} to 2.8 mg kg^{-1}. Table 3 presents correlation results of Cu with some soil properties. Copper content of soil significantly correlated with exchangeable acidity and pH (KCl), but not with pH (H_2O). The variation in soil Cu attributable to the two variables was 67% in both zones. Available Cu in these soils appears to be influenced by a combination of the acidity of the soil solution and reserved acidity in the soil colloids. The regression equation was {Cu=-0.33+ (0.72*pHKCl X) + (-3.5*Exch.Acid X). Available Cu was adequate in all soils.

Sand was the dominant particle fraction, comprising between 75 and 91% of total soil particle fraction. Mean values for sand in Iwo and Oshogbo were similar (Table 1). These results are typical of soils within this region generally described as sandy in texture and well drained (Salako et al. 1999). From soil texture analysis, most of the soils fall into the sandy loam class, with few exceptions; a lone field from Iwo zone classified as sand and another one from Oshogbo zone classified as loamy sand. All soils consisted of less than 10% clay by proportion.

3.3 Comparison of Soil Physical and Chemical Properties between Iwo and Oshogbo Zones

Statistical analysis (P = .05) indicated no significant differences between both zones for soil pH, organic matter, macronutrients (N, P, K, Ca, Mg) and exchangeable acidity. Similarly, differences in soil particle fractions, available Zn and extractable Cu were small between zones and did not prove statistically significant.

3.4 Soil Fertility Status, Fertilizer Use and the Quest for Increased Sustainable Cassava Production in Osun state

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The success of the "cassava initiative" program is hinged on efficient and stable production and marketing channels to serve both domestic industries and export markets. To achieve this both land area under cassava and yield per hectare must increase. Even at the current rate of 2 million ha under cassava, a modest increase in national yield average to 15 t ha^{-1} would increase production by 8 million tonne per annum. Push factors such as government support, new varieties, better farming practices and farmer motivation are some typically cited means of increasing yields (Philips et al., 2004).

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} when 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). Fertilizer use in Nigeria is quite low, estimated at 13 Kg ha^{-1} (FMARD, 2010), and of this projected amount, crops like maize are more likely to receive a greater proportion. 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, adulteration and high cost (Liverpool-Tassie et al., 2010). 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. 2007). 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 needs to 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

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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 (Bessho and Bell,1992 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 compare P use efficiency of cassava using phosphate rock or commercial fertilizers as P sources.

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 and multiple nutrient deficiencies show up. 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 e.g. available nitrogen supply, cation exchange capacity) 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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