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EVALUATION OF WATER YAM (*DIOSCOREA ALATA L*) GENOTYPES FOR YIELD AND YIELD COMPONENTS IN ABAKALIKI AGRO- ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT
Six Dioscorea alata genotypes were evaluated alongside a popular cultivar in the locality for yield and yield components in 2004 and 2005 at the Department of Crop Production & Landscape Management, Ebonyi State University, Abakaliki. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results indicated significant effects of genotype, cropping season and their interaction on most of the traits studied. Genotypes with potentials for multiple-tubering were identified. The genotype, TDa 98/01176 produced the highest total number of tubers, number of ware tubers and number of seed tubers per plot. Similarly, TDa 98/01176 had the highest total fresh tuber yield. The lowest values for these traits were obtained for Okwalenkata, a landrace genotype. The genotypes performed better in 2004 than in the 2005 cropping season, and three genotypes TDa 9801176, TDa 98/01169 and TDa 98/01166 had the most stable yield across the two cropping seasons. The tuber yields of these genotypes were higher than the mean yield of all the genotypes.

Key word: *Dioscorea alata*, genotypes, cropping season, evaluation, yield components

INTRODUCTION
Yams (*Dioscorea spp.)* are important tuber crop and staple food for millions of people in many tropical and subtropical countries. It has become a cash crop in countries along the coast of West Africa (Egesi *et al.*, 2005). They produce edible starchy storage tubers, which are of cultural, economic, and nutritional importance in the tropical and subtropical regions of the world (Coursey, 1967). Generally, yam tubers are boiled, roasted, baked, or fried. However, in some regions, the tubers are boiled and then pounded to glutinous dough called "fufu." Cooked yam tubers or their products are usually eaten in association with protein-rich sauces. It has also gained importance in pharmaceutical industries (Hahn, 1995).

Nigeria accounts for about 70% of the world's production of yam, generating a global annual output of over 33 million metric tones (FAO, 2000). *D. alata* is popular and prevalent in Abakaliki agro ecological zone of Ebonyi State, Nigeria where it is called "Mbala or Nvula" (Igbo names). This popularity is attributed to its rapid multiplication; high yields and extended shelf life. The slicing of the tuber for planting is also very simple and it multiplies in quadruplicates.

Yam yields are influenced by numerous environmental factors such as water (soil moisture), temperature, light and photoperiod (Orkwor and Asadu, 1998). Other constraints to yam production include biotic factors such as pests and disease organisms in the field and in the store. These factors have led to decrease in production over the years and have prompted breeding activities to generate high yielding varieties with some tolerance to environmental stresses. Therefore, the objective of the experiment was to evaluate seven *D. alata* genotypes for their yield and performances in Abakaliki agro-ecological zone of southern Nigeria.

MATERIALS AND METHODS

Experimental Site and Genetic Material: The research was conducted at the Department of Crop Production & Landscape Management, Ebonyi State University, Abakaliki, in 2004 and 2005. Abakaliki is located approximately on latitudes 6^0 04' N, and longitudes 8^0 05' E, at an elevation of 48 m above sea level. It is in the derived savannah zone southern Nigeria. The climate is characterized by daily temperature ranging from 22 °C to 32 °C. It has a pseudo-bimodal rainfall pattern from April to November. Total annual rainfall ranges between 1500 – 2000 mm, with a mean of 1,800 mm and in form of intensive violent showers of short duration (EBADEP, 2005). The soil belongs to the order ultisol with Ezzamgbo soil association and is classified as Typic Haplustult (FDALR, 1985), which is largely loam ranging from medium to high fertility and indicating suitability for agriculture.

Six *D. alata* genotypes obtained from International Institute of Tropical Agriculture (ITTA): TDa 98/01176, TDa 98/01166, TDa 98/01168, TDa 99/01169, TDa 99/00240 and TDa 297 (the Institutional check) were evaluated alongside the best locally cultivated variety called *Okwalenkata*.

Experimental Design: Setts of about 200 g of D. alata genotypes treated with Emofarm dust (mixed with water) were planted in a Randomized Complete Block Design (RCBD) with three replications, under rainfed conditions. Plant spacing was 1 m x 1 m in ridges. The yam vines were staked with about 2m stakes one month after emergence. Fertilizer application (N.P.K 12-12-17, 400 kg/ha) was by broadcast ten weeks after planting, while weeding was done three times before harvest.

Data Collection and Analysis: Data were collected on the following yield parameters at harvest: total number of tubers harvested from the sample plots, number of ware tubers (tubers above 1 kg) harvested per plot, number of seed tubers (tubers below 1 kg) harvested per plot, yield of ware tubers (t/ha), yield of seed yams (t/ha), total fresh tuber yield (t/ha). A combined analysis of variance for the two-year data (2004 and 2005) was done using the GLM procedure in SAS (SAS Institute, 1999), following the model below:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \gamma_k + \varepsilon_{ijk}$$

Where,

Y_{ijk} = the observed performance of the ith genotype in the jth cropping season in the kth replication,

μ = the overall mean of the trait,

α_i = the effect of the ith genotype (i=1,2,...7),

β_j = the effect of the jth cropping season, (j=1 and 2)

$(\alpha\beta)_{ij}$ = the genotype x cropping season interaction

γ_k = the effect associated with the kth replication (k=1,2,3)

ε_{ijk} = the residual associated with each observation.

Thereafter, reduced models, which excluded cropping season effects (separate analysis for each cropping season), were used to estimate performance of the genotypes for each cropping season. Thus, comparisons were made between estimates based on combined analysis and those using data subsets for cropping season. This would indicate genotypes that were consistent in performance across cropping seasons.

Genotype by trait analysis using GGE biplot analysis (Yan and Kang, 2003) was used to determine which variety was best and for what trait. This would aid selection of genotypes for the agro-ecological zone.

RESULTS AND DISCUSSION

Variance estimates of *D. alata* genotypes for yield and yield components:

Significant genotype effect ($P < 0.05$) on total number of tubers harvested was recorded in this experiment, while number of ware tubers harvested per plot, yield of ware tubers and total fresh tuber yield (t/ha) was very highly significant ($P < 0.001$). The effect of genotype on number of seed tubers harvested per plot and yield of seed tubers was not significant (Table 1). Cropping season effect on the number of seed tubers harvested per plot and yield of seed tubers (t/ha) was highly significant ($P < 0.01$), and very highly significant ($P < 0.001$) for number of ware tubers harvested per plot, yield of ware tubers (t/ha) and total fresh tuber yield (t/ha).

Genotype x cropping season interaction was significant for yield of ware tubers (t/ha) and total fresh tuber yield (t/ha) only.

Table 1. Variance estimates for yield and yield components of *D. alata* genotypes after two cropping seasons in Abakaliki agro-ecological zone

Source	DF	Total number tubers/plot	Number of ware tubers/ plot	Number of seed tubers/ plot	Yield of ware tubers (t/ha)	Yield of seed tubers (t/ha)	Total fresh tuber yield (t/ha)
Replication	2	19.8	0.7	19.6	4.9	0.4	5.5
Genotype (G)	6	2618.5*	487.3***	1273.4	75.1***	10.8	95.9***
CSeason (S)	1	348.6	5600.6***	8743.7**	1435.0***	41.8**	984.1***
G*S	6	993.2	69.4	1061.6	38.7***	8.2	21.8**
Error	26	1003.3	42.1	1156.4	7.8	6.1	6.0

Note: *, **, *** means significant at 5 %, 1 % and 0.1 % level of probability, Cseason means Cropping season

Table 2. Mean yield and yield components of *D.alata* genotypes grown for two cropping seasons in Abakaliki agro-ecological zone

Variety	Total number tubers	Number of ware tubers tubers/ plot	Number of seed tubers/ plot	Yield of ware tubers (t/ha)	Yield of seed tubers (t/ha)	Total fresh tuber yield (t/ha)
Tda240	76.3	30.2	46.2	14.9	4.4	19.3
Tda297	69.5	26.0	43.5	9.0	5.3	14.3
TDa 98/01166	88.5	36.5	52	13.0	5.2	18.2
TDa 98/01169	68.3	29.8	38.5	12.7	4.0	16.7
TDa 98/01169	94.5	30.0	64.5	12.4	6.5	18.9
TDa 98/01176	126.7	45.3	81.3	15.8	7.9	23.5
'Okwalenkata'	71.3	16.0	55.3	5.5	5.7	11.2
LSD 0.05	37.6	7.7	Ns	3.3	2.9	2.9

Note: ns means non-significance at 5 %. Level of probability

Mean performance of *D. alata* genotypes for yield and yield components:

The highest number of tubers harvested in this experiment was obtained for TDa 98/01176 (126.7). This was not different from value obtained for TDa 98/01169 but differed significantly from the values obtained for the other genotypes which were statistically the same (Table 2). Similarly, the highest mean number of ware tubers harvested per plot was obtained for TDa 98/01176 (43.3), followed by TDa 98/01166 (36.5). The values obtained for TDa 98/01169, TDa 98/01168 and TDa 240 did not differ significantly. The lowest mean number of ware tubers was obtained for *Okwalenkata*, a landrace genotype.

The highest mean yield of ware tubers (15.8 t/ha) was obtained for TDa 98/01176. This was not statistically different from values obtained for TDa 240 (15.0 t/ha), TDa 98/01166 (13.0 t/ha) and TDa 98/01168 (12.7 t/ha), but differed significantly from the value obtained for TDa 98/01169 (Table 2). The lowest value (5.5 t/ha) was obtained for 'Okwalenkata', the popular landrace in the locality. A similar trend was observed for total fresh uber yield. The highest value was obtained for TDa 98/01176 (23.8 t/ha), followed by TDa 240 (19.3 t/ha) and TDa 98/01169 (19.0 t/ha), while *Okwalenkata* had the lowest value for the trait. The new genotypes out yielded both the Institutional check (TDa 297) and the popular landrace (*Okwalenkata*) indicating a possible adoption of the new genotypes instead of the landraces especially if their functional and physico-chemical properties are desirable. This result is expected because hybrids have been known to perform better than their unimproved counterparts. According to Obi (1991), hybrids are products of two or more parents of good agronomic characteristics and in most cases should perform better than either of their parents.

TDa 9801176 ranked the best among the genotypes studied, clustering with most of the traits based on Genotype by Trait plot (Fig. 1). Similarly, the means versus stability plot indicated TDa 9801176, TDa 98/01169 and TDa 98/01166 to be more stable and better adapted in Abakaliki agro-ecological zone (Fig 2). Future preference of these genotypes over the popular cultivar in the locality may be strengthened by the findings of Udensi *et al.*, (2006) that two of these genotypes, TDa 99/00169 and TDa 98/01176 have high crude protein level and could be selected for intensive cultivation in Nigeria and other *D. alata* growing regions.

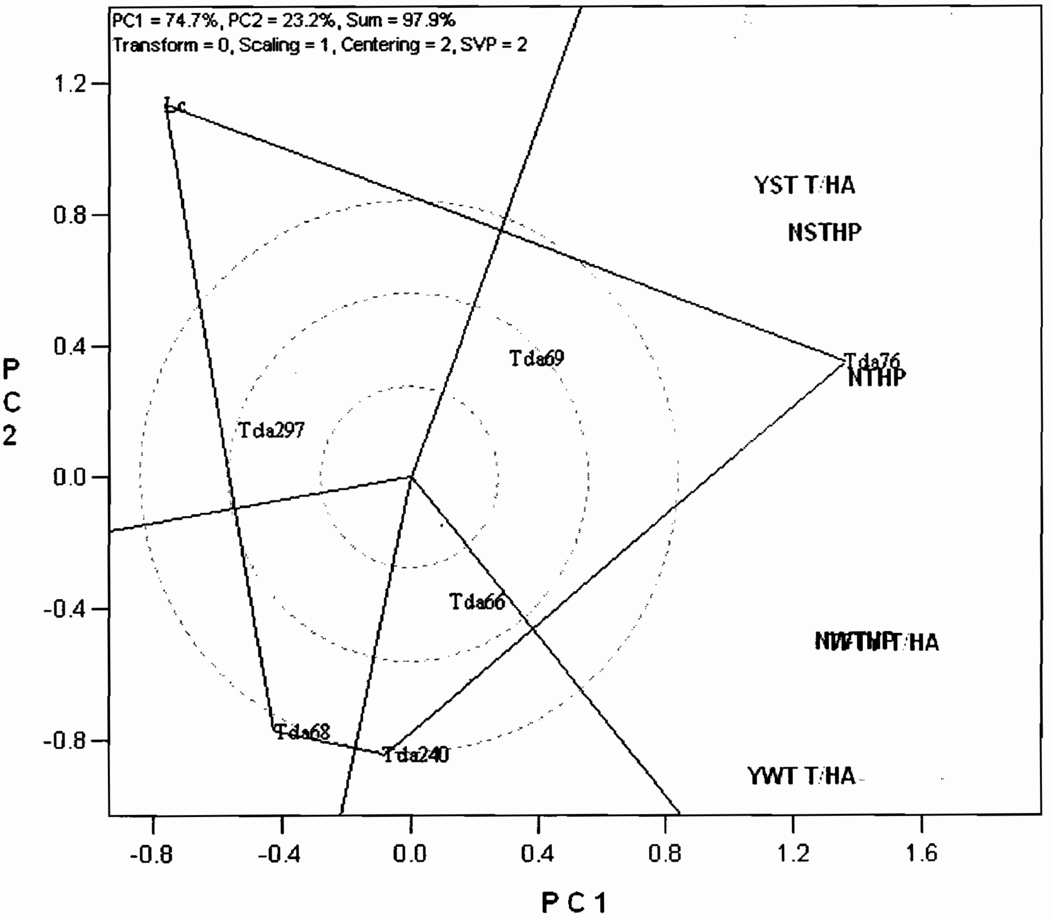

Fig. 1. Genotype x trait plot showing *D. alata* genotypes that performed best for different traits. **Note:** NTHP = number of tubers harvested per plot, NSTHP = number of seed tubers harvested per plot, NWTHP = number of ware tubers harvested per plot, YST T/HA = yield of seed tubers (t/ha), YWT T/HA = yield of ware tubers (t/ha), TFTY T/HA = total fruit tuber yield (t/ha). Tda 66 = TDa 98/01166, Tda 68 = TDa 98/01168, Tda 69 = TDa 98/01169 and Tda 76 = TDa 98/01176.

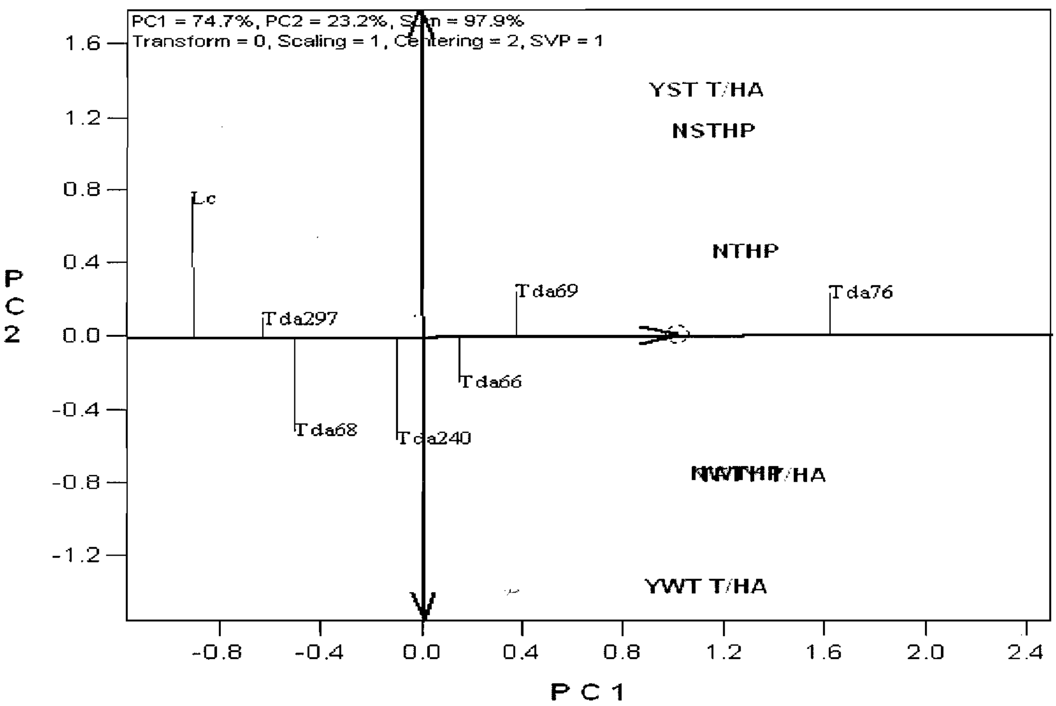

Fig. 2. Mean versus stability plot showing *D. alata* genotypes that performed best in 2004 and 2005. **Note:** NTHP = number of tubers harvested per plot, NSTHP = number of seed tubers harvested per plot, NWTHP = number of ware tubers harvested per plot, YST T/HA = yield of seed tubers (t/ha), YWT T/HA = yield of ware tubers (t/ha), TFTY T/HA = total fruit tuber yield (t/ha). Tda 66 = TDa 98/01166, Tda 68 = TDa 98/01168, Tda 69 = TDa 98/01169 and Tda 76 = TDa 98/01176.

Cropping season effect on the performance of *D. alata* genotypes for yield and yield components: *D. alata* genotypes performed better in 2004 than 2005 (Table 3) for number of ware tubers harvested per plot, yield of ware tubers (t/ha) and total fresh tuber yield (t/ha), while the reverse was the case for number of seed tubers harvested per plot and yield of seed tubers (t/ha). In terms of total fresh tuber yield, the most responsive genotypes in 2004 in descending order were TDa 98/01176, TDa 240, TDa 98/01169 and TDa 98/01168, while in 2005 the most responsive genotypes were TDa 98/01176, TDa 98/01166, TDa 98/01169 and TDa 240 (Table 4). In the two cropping seasons, TDa 98/01176 was stable in performance giving the best yield.

Table 3. Cropping Season effects on the performance of *D.alata* genotypes grown in 2004 and 2005 in Abakaliki agro-ecological zone

Variable	2004	2005	LSD $_{0.05}$
Number of ware tubers (tubers above 1 kg)/plot	42.1	19.0	4.1
Number of seed tubers (tubers below 1 kg)/plot	40.1	68.9	21.6
Yield of ware tubers (t/ha),	17.8	6.1	1.8
Yield of seed yams (t/ha)	4.6	6.6	1.6
Total fresh tuber yield (t/ha)	22.3	12.6	1.5

Table 4. Mean yield of ware tubers and total fresh tuber yield (t/ha) of *D.alata* genotypes in 2004 and 2005 cropping seasons in Abakaliki agro-ecological zone.

low crop yield. Ruthenberg (1980) argued that intensification of traditional farming systems postpones, but does not avert involution and eventual impoverishment due to population growth. This paper compares soil properties (Avail P, Total N, organic matter, pH (H_2O), Ca^{++}, K^+, Mg^{++}, Na^+, TEB, TEA, ECEC, BS, EPP, ESP, C:N ratio, Mg:K ratio, Ca:Mg ratio) between high and low population pressure areas on one hand, and between good and poor market access areas on the other hand. Earlier studies on the effect of intensification on soil properties (Lagemann 1977) was restricted to only three villages of one state in southeast Nigeria, and population pressure was the only factor considered. The present study not only presents a wider coverage (four countries of sub Saharan Africa) but also includes market pressure as a factor in land use intensification. The aim was to examine the effect of agricultural intensification on soil properties. The two indices had earlier been listed as factors that drive land use intensification.

MATERIALS AND METHODS

Site Selection and Sampling Procedures

Climate, human population density, and market infrastructure formed the bases for sampling. Following Carter and Jones (1989), four basic climatic zones were defined from temperature and duration of dry periods within the growing seasons (see also Jones 1988) (Table 1).

All-weather roads, railways and navigable rivers were derived from the 1987 Michelin travel maps and used to create a market access infrastructure map of sub-Saharan Africa. This map was divided into good and poor zones according to the density of the roads, railways or navigable waterways (see also Asadu et al. 2007).

Population data from the United States Census Bureau (unpublished data), projected forward to 1990, were used to calculate population densities and to create a population map of Africa. This map was divided into high and low demographic pressure zones, the former comprising areas with 50 or more persons per km^2 (see also Nweke et al. 1994)

The three maps of climate, population density and market access infrastructure were overlaid to create zones with homogeneous climate, demographic pressure and market access condition. This was done with the help of a geographical model, IDRISI (Eastmann 1988). Each climate/population density/market zone with < 10 000 ha of cassava in each country was excluded as unrepresentative of cassava-growing areas. The remaining areas, which formed the potential survey regions, were divided into grids of cell 12' latitude by 12' longitude to form the sample frame for site selection. In each country, a certain number of grid cells, determined by the size of the country, were distributed among the climate/population density/market zones, in proportion to the sizes of the zones and were randomly selected. The total number of grid cells for the four sampled countries (Cote d'Ivoire, Nigeria, Tanzania and Uganda) is 181 (figure 1). One village was selected, by a random method, within each of the grid cells.

Table 1: Definitions of Climate and Altitude Zones

Characteristics			
Zone	**Daily temperature (^{0}C)**		**Dry season**
	Mean	**Range**	**(months)**
Lowland humid (LLH)	>22	<10	<4
Highland humid (HLH)	<22	<10	<4
Sub-humid (SH)	>22	>10	≤6
Non-humid (NH)	>22	>10	7-9
Low altitude (LA)	<800 meters above sea level (masl)		
Mid altitude (MA)	≥800 meters above sea level (masl)		

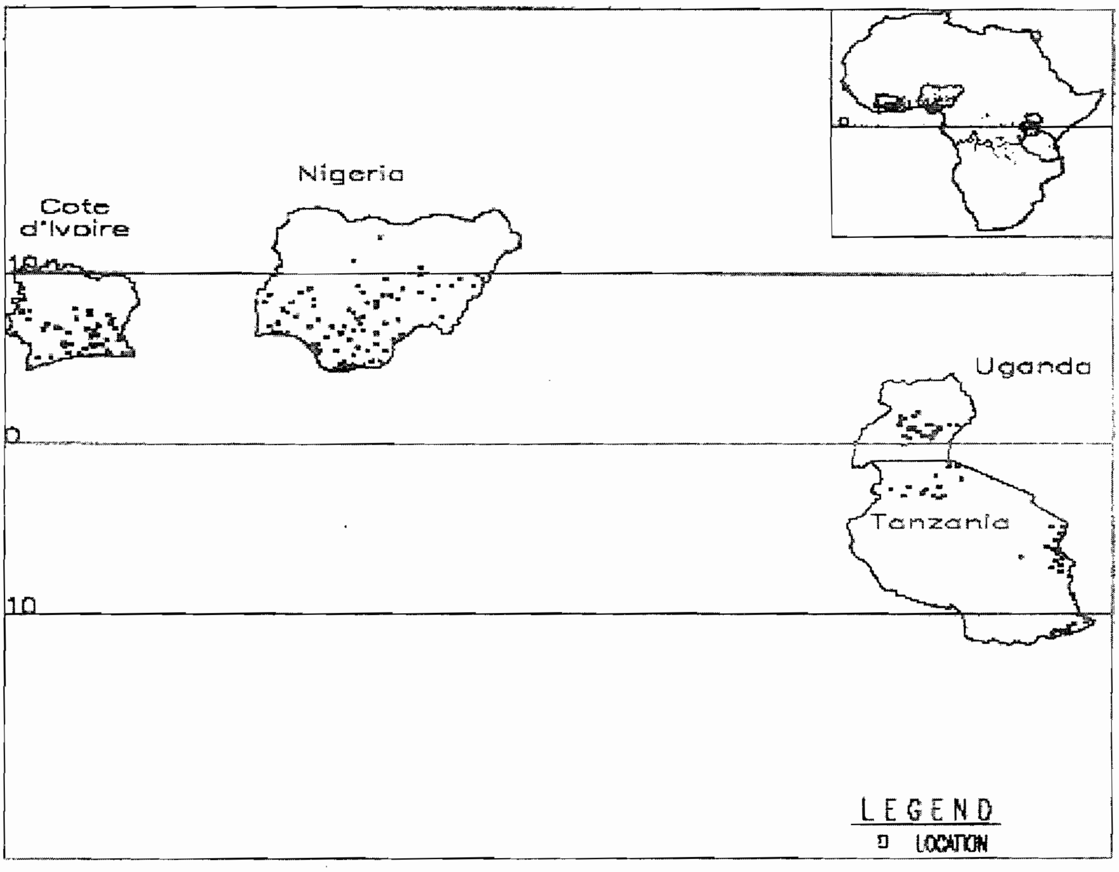

Figure 1. Locations of the villages

In each selected village, a list of farm households, was compiled and grouped into 'large', 'medium', and 'small' smallholder units with the assistance of key informants. One farm unit was selected from each stratum (Nweke et al. 1994). Cassava yield data were then taken from fields 9-12 months old; this being the most frequent age of harvest in the areas surveyed. Soil samples were collected from all the fields (plots) of the three selected farmers from where cassava yields were taken at 0-20 cm and 20-40 cm depth using a posthole auger. Two or more auger points were systematically selected depending on the homogeneity of the field to represent each field. Samples from each field were bulked separately before analysis. Where the field was sloping, it was divided according to slope position and samples from each topographic position bulked and analyzed separately. The altitude of each field was measured with an altimeter and all the fields were classified into either low (< 800 masl) or mid (≥ 800 masl) altitude fields

All the laboratory analyses were done in the Analytical Service Laboratory of the International Institute of Tropical Agriculture (IITA), Ibadan following standard procedures outlined in the IITA (IITA 1982) Laboratory Manual. Soil properties determined include: particle-size distribution, organic matter, total N, available P, total S, exchangeable bases, exchangeable acidity, and total Mn, as well as soil pH (H_2O). Various nutrient ratios were also calculated

RESULTS AND DISCUSSION

Fallow Systems

Following Greenland (Greenland 1974), the COSCA study classified fallow periods into three: long fallow which denotes less than 10 years of continuous cultivation fallowed by 10 or more years of fallow; short fallow: referring to less than 10 years of continuous cultivation combined with less than 10 years of fallow between crops; and continuous cultivation involves at least 10 years of continuous cropping with less than one year of fallow between crops.

About 20% of the village fallow systems were continuous cultivation, 75% short fallow and only 5% were long fallow systems. Intervillage variations in the fallow systems were due to demographic (Lagemann 1977) and market pressures (Nweke et al. 1994). Lagemann (1977) noted that farmers are able to change cultural practices and systems in response to increasing population pressure. For instance, about 30% of the high population village fallow systems were under continuous cultivation as against about 15% in the low population village fallow systems (table 2). Similarly, about 25% of the good marked access villages had continuous cultivation fallow systems compared to only about 10% in the poor market access areas (table 2).

Organic Manuring

Organic manuring was considered practiced if organic matter was brought in from outside to add to plant residues if any, already available in the field. Organic matter often brought into the field from outside included animal waste, household waste, etc composted or fresh, all with the aim of regenerating depleted soil nutrients

Overall, the application of this intensive system in the study area was very low covering only 5% of the arable crop fields. The practice was more common in good than in poor market access areas, and in high than in low population density zones (table 3). The most important form of agricultural intensification is the substitution of manure for fallowing as the principal means of maintaining soil fertility (Ebo 1990).

Livestock Grazing

Livestock grazing was considered practiced if the field was grazed with sheep, goats or cattle prior to planting. The soil fertility value of livestock grazing is in the difference between the soil nutrients added by the droppings and that lost by the vegetation removed. For instance, it is expected that soils where animals graze under confinement will receive more animal droppings than those where they graze under free range.

Livestock grazing was practiced in an average of about 15% of the arable crop fields surveyed. It was more common around market centers and in high population density zones than in areas remote from market centers and in low population density zones (table 3). Nweke et al. (1994) observed that while fallow periods declined as population density increased, the use of land use intensification practices such as livestock grazing became more frequent in an effort to counter the effect of reduced fallow on yield.

Table 2: Percentage distribution of village fallow systems by population and market zone in SSA

Zone		No. of systems	Percentage Continuous cultivation	Short fallow	Long fallow	Total
Population density	high	275	28	70	3	100
	low	235	14	80	6	100
Market access	good	163	23	70	7	100
	poor	55	9	84	7	100

Table 3: Percentage distribution of arable fields by soil fertility management practices by market and population zone in SSA

Zone	N	Percentage Organic Manuring Practiced	Not practiced	Total	Livestock Grazing Practiced	Not practiced	Total
Market access:							
Good	785	6	94	100	13	87	100
Poor	183	2	98	100	8	92	100
Population:							
High	1309	8	92	100	13	87	100
OLow	931	2	98	100	7	93	100

N = Number of fields

Inorganic Fertilizers

On the average, inorganic fertilizers were used in less than 10% of the fields, all in Nigeria. They were not reported used in any of the fields surveyed in Cote d'Ivoire, Tanzania or Uganda. Compared to the last three countries, Nigeria had better market access conditions (Nweke et al. 1999). It is to be noted that inorganic fertilizer application is an intensive system which is more common in good than in poor market access areas. Land use intensification is always accompanied by fertilization practices to make up for the period of natural regeneration (fallow period) which range from ash fertilization to a combination of methods including artificial fertilization (Ebo 1990).

Comparing Soil Properties Across Population and Market Pressures

From this study, the applications of organic manure and other intensification practices generally increased as population density increase. This is reflected in the differences in the soil properties between high and low population density zones. The higher levels of available P, total N, and exchangeable Ca in the soils of the higher population density zone reflect the higher level of organic matter use in the zone (table 4). Lagemann (1977) observed greater use of household refuse and organic manure in high than in low population density villages in southern Nigeria. In addition, K^+, EPP, C:N and Ca:Mg ratios were also higher in the soils of the higher population density zone. On the other hand, the higher levels of TEB and ECEC in the soils of the low population density zone which imply a higher overall nutrient reserve, (Asadu et al. 1998) may be a reflection of long fallow periods. In addition, pH, Mg^{++}, and Mg:K ratio were higher in low population density soils. The above suggest that the intensification practices at the high population density zones may not be sufficient to avert soil degradation. Nweke et al (1994) noted that the low frequencies of land use intensification practices in the high population density areas make it difficult to raise the level of cassava root yield in the area

There were also significant differences between the good and poor market access zones in all the mean values of soil properties except available P and total N (table 5). The levels of exchangeable K, Mg, Na and pH and particularly of both TEB and ECEC were significantly higher in the soils of the poor than in the good market access zones. This also implies a higher nutrient reserve (Asadu et al. 1998) in the soils of the poor market access than those of the good market access zones. Fallow periods were significantly longer in the poor than in the good market access areas (Asadu and Nweke 1999). Thus, the better soil conditions in the poor market access areas could be because of the longer period of natural soil regeneration. In addition, farmers in the good market access areas are usually undercapitalized to use adequate and appropriate specification of purchased inputs that can counter the effect of short or no fallow on soils. (Enete and Achike 2008)

Table 4: Mean values of soil properties by human population densities in SSA at soil depth of 0-40 cm

Soil properties	Low (N = 650)	High (N = 1280)	LSD (0.05)
Avail P(mg/kg)	7.6	9.8	1.48
Total N (%)	0.105	0.120	0.033
OM (%)	1.95	2.21	0.15
pH (H_2O)	8.99	6.0	0.08
Ca^{++} (cmol/kg)	4.26	4.35	1.19
K^+ (cmol/kg)	4.28	0.34	0.04
Mg^{++} (cmol/kg)	3.74	1.81	0.44
Na^+ (cmol/kg)	0.32	0.34	0.023
TEB (cmol/kg)	13.33	6.83	1.35
TEA (cmol/kg)	0.56	0.62	0.129
ECEC (cmol/kg)	13.89	7.45	1.35
BS (%)	87.1	87.7	1.93
EPP (%)	30.8	4.6	4.38
ESP (%)	2.3	4.6	0.46
C:N ratio	10.6	12.9	0.76
Mg:K ratio	46.2	8.1	11.5
Ca:Mg ratio	3.4	5.1	0.57

Notes: N = number of fields; OM = organic matter, TEB = total exchangeable bases, TEA = total exchangeable acidity, ECEC = effective cation exchangeable capacity, BS = base saturation, EPP = exchangeable potassium percentage, ESP = exchangeable sodium percentage.

Table 5: Mean values of soil properties by zones of market access conditions in SSA at soil depth of 0-40 cm

Soil properties	Good access	Poor access	LSD (0.05)
Avail P(mg/kg)	8.0	11.2	3.5
Total N (%)	0.089	0.161	0.075
OM (%)	1.66	2.94	0.35
pH (H_2O)	5.9	6.2	0.18
Ca^{++} (cmol/kg)	5.79	19.90	2.76
K^+ (cmol/kg)	0.27	0.43	0.10
Mg^{++} (cmol/kg)	2.41	8.29	0.94
Na^+ (cmol/kg)	0.32	0.40	0.05
TEB (cmol/kg)	8.80	29.03	3.13
TEA (cmol/kg)	0.43	0.34	0.29
ECEC (cmol/kg)	9.23	29.37	3.12
BS (%)	88.9	92.2	4.5
EPP (%)	2.93	1.5	0.87
ESP (%)	3.43	1.4	1.07
C:N ratio	11.7	10.6	1.65
Mg:K ratio	31.9	73.5	26.6
Ca:Mg ratio	3.8	2.4	1.32

Notes: N = number of fields: OM = organic matter. TEB = total exchangeable bases, TEA = total exchangeable acidity, ECEC = effective cation exchangeable capacity, BS = base saturation. EPP = exchangeable potassium percentage. ESP = exchangeable sodium percentage

CONCLUSIONS

The use of all the soil maintenance strategies (organic manuring, livestock grazing and inorganic fertilizer) increased with population and market pressure. However, soils of the high population density and good market access areas were found to be generally poorer in nutrient than those of the low population density and poor market access areas. Thus the study shows that the intensification practices by farmers in SSA in the high population density and good market access areas are not adequate enough to counter the effect of short/no fallow. Fallow periods were generally longer in the low population density and poor market access areas. This observation underscores the need for credit availability to smallholder farmers to enable them apply the required specification of soil maintenance strategies which can counter the effect of reduced fallow periods on soils.

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