Analytical steps to a multi-trait selection index for rapid participatory appraisal of cassava varieties for release to farmers

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Abstract

The Integrated Cassava Project of the International Institute of Tropical Agriculture conducted on-farm, demonstrational, and multilocational trials in 2003/2004 and 2004/2005. From these trials nine new elite genotypes were released to farmers. These trials required working with a lot of stakeholders including farmers and government agencies. Data on several trait variables were obtained from the field trials. This paper presents the last stage in a national breeding program, and the logic behind a decision to release or not release new varieties. It also shows how to arrive at a choice of traits and how to derive appropriate weights in a simulation model.

Keywords: Cassava, Selection index; Mosaic disease; Participatory selection; Variety release

Introduction

In 2003/2004 and 2004/2005, the Integrated Cassava Project (ICP) of the International Institute of Tropical Agriculture (IITA) conducted a series of on-farm, demonstrational, and multilocational trials in Nigeria. The aim was to evaluate 40 new cassava genotypes and identify those that were superior to current stock available to farmers. The successful lines that would be selected were expected to be resistant/tolerant to cassava mosaic disease (CMD), have increased productivity (root yield), be acceptable to processors for diverse food products, and be stable in several environments.

At the last stage in a national breeding program, the decision to release or not release a variety is taken by logically examining traits of interests. The choice of the traits to use and how to apply them in a simulation model is usually a critical task of the breeder. This paper presents the approach, the selection algorithms derived, and their applicability in similar cultivar evaluations.

Often, reports on farmers' participatory evaluation do not clearly explain the stepwise sequence and computations leading to conclusions and ultimate choice. This paper focuses on these, using a live experiment that led to the release of 9 new cassava genotypes in Nigeria.

Of all the resources used in cassava cultivation among resource-poor farmers, variety substitution is the one most often adopted. The process of selecting the best variety is the essential investment in the enterprise. In the process of screening from a pool of genotypes to provide elites for farmers, there is need to integrate many aspects. The cassava variety must meet the needs of all components of the cassava commodity chain in a defined area of project intervention. In Nigeria, prior to this new release of 9 genotypes, there had been only 17 officially released cassava genotypes. These 17 are regarded as "earlier", being at least 20 years old. A typical cassava breeding cycle is about 10 years.

The key point in the selection and release of new cassava clones is to show evidence of superior performance in any of the proposed new clones over the varieties existing in the field of cultivators. IITA has a continental mandate on cassava while the National Root Crops Research Institute (NRCRI) Umudike, has the national cassava mandate. Both institutions generate genotypes for release to farmers in Nigeria through collaborative trials. Genotypes from IITA begin with the code of TMS and those of NRCRI with NR. For many reasons, TMS 30572 is the most widespread genotype in many cassava growing areas of Nigeria.

Methodology

Field trials. On-farm trials (OFTs) were conducted by a randomly chosen set of farmers in each of the cassava growing local government council areas of 12 States in southern Nigeria. The south-south States were the following, from west to east: Ondo, Edo, Delta, Bayelsa, Rivers, Akwa Ibom, and Cross River. The south-east States comprised Anambra, Imo, Enugu, Abia, and Ebonyi. In the 2003/2004 season, 110 OFTs in each State were established but were reduced to 66 in each State in 2004/2005. The Demonstration trials (DEMOs) were planted at sites chosen in the community so that passers-by would always see them as they went about their daily activities in the village. In each of the 12 Project States there were 8 trials in 2003/2004 but the number was increased to 18 in 2004/2005. The Multilocational trials (MLTs) were established and managed by research technicians from IITA, national research institutes, universities, and private farms until harvest. The agroecological zones where cassava is grown were representatively covered by the placement of the sites for trials of this type. A total of 32 MLTs were established in 2004/2005, compared with 18 in 2003/2004.

In all these trials, 40 new clones were assessed along with three known checks (TMS 30572, TMS 4(2)1425, TMS 82/00058). These new clones were 91/02324, 92/0057, 92/0067, 92/0325, 92/0326, 92B/00061, 92B/00068, 94/0026, 94/0039, 94/0561, 95/0166, 95/0289, 95/0379, 96/0523, 96/0603, 96/1089A, 96/1565, 96/1569, 96/1632, 96/1642, 97/0162, 97/0211, 97/2205, 97/3200, 97/4763, 97/4769, 97/4779, 98/0002, 98/0505, 98/0510, 98/0581, 98/2101, 98/2226, 99/2123, 99/3073, 99/6012, M98/0028, M98/0040, M98/0068, and TME 419.

Choice of breeder candidate genotypes. The 40 elite lines used in these trials were selected by IITA, based on certain criteria. The reason was that IITA was assigned the duty to mitigate the spread of CMD and also to improve farmers' yields with lowest input of resources. The criteria were as follows

- CMD resistance/tolerance (score of <1.04 on severity scale 1–5).
- Multiple pest resistance/tolerance (score of <1.04 on severity scale 1–5; root rot [<5% incidence]).
- High and stable yields (<11 t/ha baseline, aim >20 t/ha).
- High dry matter (>24% baseline, aim >30%).
- General feedback on acceptability from Uniform Yield Trials.

Data used for index. At the end of field and root evaluation, data were collected on several traits, such as disease incidence, and disease severity (each for 5 diseases). These were CMD, bacterial blight(CBB), anthracnose disease (CAD), green mite (GCM), and root rot. Other traits were agronomic features (establishment ability at harvest, FYLD (FYLD), yield of standard stakes 20–25 cm, sprouting ability, number of plants at harvest), proximate composition of dry root (dry matter content (%), starch (%), protein (%), ash (%), fibre (%), proportion of amylose to the starch (%). Also considered were use for human food (gari, fufu, wet starch), livestock feedstuff (forage yield), and industrial raw material (dry yield of peeled roots, conversion ratio to flour). Details of the kind of data collected from the three trials are shown in Tables 1 and 2.

Derived variables for index development. To enable utilization of most variables which are covariates in the selection process a couple of new variables were derived from the raw data received from trials.

- Dry yield (DYLD): This is a product of dry matter percentage (DMC) and FYLD (FYLD) expressed in t/ha.

$$DYLD = \frac{DM}{100} \times \frac{FYLD}{1}$$

where FYLD = FYLD (t/ha).

- ESTAB= (actual number of plants at harvest/expected number of plants).
- CMD-index (CMDSI): Mean of the product of each of three assessments of CMD incidence (CMDI) and severity (CMDS) multiplied by their respective weights. Weights were introduced based on expert advice about when the disease most affects the root yield.

$$CMDSI = \left(\frac{((CMDI1 \times CMDS1) \times 0.75) + ((CMDI3 \times CMDS3) \times 1) + ((CMDI6 \times CMDS6) \times 0.25)}{n} \right)$$

where n = relative number of variables with values available for each clone in this calculation

- CBB-index (CBBSI): Mean of the product of each of three assessments of CBB incidence (CBBI) and CBB severity (CBBS). CBB was assessed at 1, 3, and 6 MAP.

$$CBBSI = \left(\frac{((CBBI1 \times CBBS1) \times 1) + ((CBBI3 \times CBBS3) \times 1) + ((CBBI6 \times CBBS6) \times 1)}{n} \right)$$

where n = relative number of variables with values available for each clone in this calculation

- CAD-index (CADSI): Mean of the product of each of two assessments of CAD incidence (CADI) and CAD severity (CADS). CAD was assessed at 9 and 12 MAP.

$$CADSI = \left(\frac{((CADI9 \times CADS9) \times 1) + ((CADI12 \times CADS12) \times 1)}{n} \right)$$

where n = relative number of variables with values available for each clone in this calculation

- CGM-index (CGMSI): Mean of the product of each of two assessments of CGM incidence (CGMI) and CGM severity (CGMS). CGM was assessed at 9 and 12 MAP.

$$CADSI = \left(\frac{((CADI9 \times CADS9) \times 1) + ((CADI12 \times CADS12) \times 1)}{n} \right)$$

where n = relative number of variables with values available for each clone in this calculation

- Root rot–index (RootrotSI): This is the proportion of rotted roots to the total number of roots.
- Root shape/size (RTSHPSI): square root of product of root shape by root size scores.
- Other diseases complex index (OTHDISSI): This is a weighted average of CBBSI, CADSI, CGMSI, and RootrotSI.

$$OTHDISSI = \left(\frac{CBBSI + CGMSI + (CADSI \times 2) + (RootrotSI \times 2)}{n} \right)$$

where n = relative number of variables with values available for each clone in this calculation

Indices CADSI and RootrotSI had a weight of “2” because of their perceived relative importance over the other two indices in the context of cassava utilization in south-south and southeast Nigeria. CAD will reduce the market value of cassava stems, but root rot reduces the quality and quantity of roots, especially in southern Nigeria which is very humid. In the 2003/2004 evaluation, RootrotSI was treated as a separate variable.

Approach to data analyses. There were eight major steps that resulted in the final selections of clones. They are listed stepwise as follows:

- OFTs evaluation, to select top 10 clones per State (OFTs select).
- DEMOs evaluation, to select top 10 clones per State (DEMOs select).
- Selection of top 10 clones per State across the top 10 lists from State OFTs select and DEMOs select (State select).
- Selection of top 10 clones across all the States from each State’s select list that were derived from OFTs and DEMOs.
- MLTs evaluation, to select top 10 clones per MLT.
- Selection of top 15 clones across all MLTs.
- List of 15 most frequent selected clones across the MLTs and across the State lists. So if a clone appeared in the State top list and also appeared in the MLT top list, it would be said to meet both farmers’ and researchers’ desires.
- Genotype × Environment stability test on the final candidates.

At the end of the evaluations and selection, 5 top clones were recommended each year by a Technical sub-committee (TSC) to the Variety Release Committee (VRC) in Nigeria for official release consideration because they occurred at the top in all the preliminary selections and were stable across environments. Location-specific clones were not discarded but kept in the database to be suggested to farmers at that site.

Based on decisions of stakeholders at the data review meetings (technical partners, scientists, farmers, industrialists, traders), certain basic expectations about the choice of candidate clones were outlined. It was agreed that the varieties to be recommended to VRC must have a FYLD greater than 15 t/ha, and DYLD of not less than 30%. DYLD was most important to balance the needs of the farmer and of the processor. The chosen candidates must also be good for processing into gari, have good plantable stem weight, good plant formation, high stake yield, and be highly tolerant/resistant to CMD and other pests. The review meetings also gave an insight on how well each of the trials had been executed in each site. These key guidelines enabled data analysts to select the important variables to be considered for each type of trial and decide on the acceptable data quality for results to be admitted from a trial (Table 3).

Every farmer who participated in OFTs in each State did not test all the 40 varieties. Each of the farmers had 3 of the elite lines plus TMS 30572 and their own choice of the best local variety. To poll all the data from visual assessments by farmers for the 40 new genotypes and 3 checks, an index was computed that would enable ranking across the 43 genotypes. The calculation of the index is explained using an example for one variable (root shape) in a State (Table 4). All quantitative data from the OFTs were analyzed using an augmented design.

For the DEMOs each of all the farmers who participated had the 40 varieties. All farmers' visual assessments were based on a ranking of 1 to 3 and a matrix, like that shown in Table 4, was also used to derive the index for assessment. All quantitative data from DEMOs were subjected to analysis of variance using SAS after the elimination of outliers that fell short of criteria agreed in the data review meetings (SAS 2003).

Selecting for top 10 clones per trial. OFT and DEMO evaluation and selection top 10 clones
The means tables from OFT/State and DEMO/State were sorted by each of 5 key assessment variables (Table 3). For each variable the clones were ranked from 1–43. Making use of a combination of FREQUENCY and RANK SUM statistics (Baker, 1986; Onyeka et al 2005; Egesi et al 2006), the top 10 clones were selected for each OFT/State and DEMO/State (Table 5). Within their respective categories, more weight was applied to FYLD which was a measured quantitative variable than to the other four qualitative variables from the farmers' assessment.

Selecting of top 10 clones per State. All top 10 clones from the OFTs and DEMOs were assigned numbers from 1 to 10 as they appeared in the calculations to be described below. To combine both the top 10 list from OFTs, and top 10 list from DEMOs per State, a method constituting a combination of frequency of occurrence of clones in both lists (FREQUENCY) and the sum of the positional ranks (RANK SUM) was utilized. See Table 5 for an example. For this particular case, a weight of 2 was applied to the DEMO selection, so that when the result was a tie with he OFT selection. The DEMO selection would be preferred. The decision about putting a preferred weight on the DEMOs compared to OFTs was reached by all implementing partners who agreed that the DEMOs were executed better than the OFTs. An example of the procedure is presented as follows:

- Get the frequency of each clone from the two lists (column A).
- Get the position rank assigned to each clone from the lists (columns B and C).
- Divide the value of the position ranks from DEMO by 2 (column D). This is a weight introduction to enable the preferred selection of clones from DEMO list when there is a tie.
- Add the value of the position rank in OFT (column B) to the weighted position rank of DEMO (column D). See column E.
- Calculate the mean rank sum by dividing column E in STEP 4 with column A in STEP 1 (column F).
- Calculate the inverse of the mean rank sum in STEP 5 (column G).
- Divide the frequency (STEP 1) by the number of tables being combined (in this case 2 tables, OFT and DEMO). See column H.
- Multiply the inverse mean rank sum (STEP 6) by the proportion of frequency (STEP 7). See column I.
- Multiply "column I" by a constant, for example 100, to convert to larger values (optional). See column J.
- Sort "column J" (STEP 9), in descending order and pick the first 10 clones. In the event of ties at the tenth position, select all the clones that had the same index value as the tenth clone

After the top 10 clones for each State has been calculated, the above method was used to combine all top 10 lists from each State to produce the top 10 clone list for all States.

MLTs evaluation and selection of the top 15 clones. In 2003/2004 MLT evaluation, this procedure of FREQUENCY and RANK SUM combination method was also used to combine all the top 10 clone lists from the 18 MLTs. The variables considered in each MLT were CMDSI, DYLD, (OTHDISSI), RootrotSI, and (RTSHPSI). These five variables were used to formulate a model to compute a selection index (MLTSI).

$$MLTSI = \frac{\left(1.5\left(\frac{1}{CMDSI}\right) + 3(DYLD) + \left(\frac{1}{OthdisSI}\right) + \left(\frac{1}{RootrotSI}\right) + (RTSHPSI)\right)}{n}$$

where n = relative number of variables with values available for each clone in this calculation.

The weight 1.5 was applied to CMDSI, and 3 to DYLD, to introduce the prioritization of variables. Inversions were required for disease variables because lower values imply increasing resistance. The proportion by which each of the 40 clones was better than the mean of the check clones was then calculated from MLTSI. The output was sorted in descending order and the first 15 clones were selected.

In arriving at the top 10 list for all States and the top 15 list for MLTs no weights were introduced as in step 3 above and the divisors for the frequency in step 7 above were 12 and 18. This is because there were 12 State lists to combine into one, and 18 MLT lists to combine into one.

In 2004/2005 MLT evaluation, a more robust method, was used in deriving the MLTSI for each of the 32 MLTs. The key variables utilised were CMDSI, FYLD, DYLD, OTHDISSI, DMC, ESTAB, Nostem25. Nostem25 is the number of 25 cm stakes that can be obtained from a clone. The introduction of ESTAB and Nostem25 variables was because in 2004/2005 the cassava seed enterprise had grown and some farmers were looking for varieties that would give them more stakes to sell and establish with minimum sprout loss. RootrotSI was included in the OTHDISSI computation. A regression analysis using SAS was used to derive the estimated contribution for each of these variables to DYLD. These estimates became the weights that were applied to each of the variables in the MLTSI model thus:

$$MLTSI = \frac{\left(\left(\frac{1}{CMDSI}\right) \times 1.01\right) + (FYLD \times 1.73) + (DYLD \times 1.8) + (DMC \times 1.8) + \left(\left(\frac{1}{OTHDISSI}\right) \times 1.0\right) + (Nostem25 \times 1.03) + (ESTAB \times 1.37)}{n}$$

where n = relative number of variables with values available for each clone in this calculation.

This model was applied to the overall mean table of the 32 MLTs. The table was then sorted in descending order by the MLTSI column to obtain the top 15 clones. Tables 6 and 7 show the matrix for the 2004/2005 calculations. The index values for each trait were derived by dividing each value by the maximum score, thus a value of one indicates the clone with the best score and a value of zero indicates a clone with the worst score (Table 6). The reverse is the case for the disease variables (CMDSI and OTHDISSI) where a value of zero indicates a clone with the best score and value of one is for the worst. This way, data from each of the variables were adjusted to a unit-less form.

Contents of Table 7 are described as follows:
- Shaded cells in same column indicate clones in the top 15 position for a trait.
- Shaded cells across columns on same row indicate clones with multiple high trait value, the more the better.
- All: Index (MLTSI column)-Application of the MLTSI model using all the seven variables plus corresponding weights; Rank-Top 15 clones.
- All, except CMDSI: Index (MLTSI column)-Application of the MLTSI model using all the seven variables plus corresponding weights except CMD-index. The reason is that the initial criterion for the inclusion of these clones in the trials was a CMD score of <1.04 on a severity scale 1–5. This means that the clones were

resistant from the onset and the relative values calculated only rank them but do not connote susceptibility; Rank-top 15 clones.

- All, except all diseases: Index (MLTSI column)- Application of the MLTSI model using all the seven variables plus corresponding weights except CMDSI and OTHDISSI. The reason for this is that the initial criteria for inclusion of these clones in the trials was CMD score of <1.04 on severity scale1–5 and multiple pest resistance/tolerance (score of <1.04 on severity scale 1–5; Root rot [<5% incidence]). This means that the clones were resistant from the onset to most diseases and the relative values calculated only rank them but do not connote susceptibility; Rank-top 15 clones.

Genotype by Environment stability test on the final genotypes. Mean performance of the cassava genotypes across sites (environments) are presented in Table 8 (2003/2004) and Table 9 (2004/2005). In 2003/2004, the genotypes had mean FYLD greater than 11.2 t/ha, mean DYLD >3.73 t/ha, mean DMC >29.34%, mean gari yield >12.02%, mean No1mstm >16, and starch >69.14%. The genotype with the highest FYLD (21.90 t/ha) and DYLD (7.96 t/ha) across environments was 92B/00061. In terms of DMC, it was 96/1632 (40.30%). The highest gari yield was from TME 419 (25.01%), and the highest number of stems, 1 m length was obtained from 95/0166 (43.9). The largest volume of starch was from 94/0026 (88.9%). For all traits measured, apart from CMDSI and CNP, the coefficient of variation (CV) ranged between 5.22 and 17.91. This implies low environmental effects on each of these traits. The reaction of genotypes to disease is variable, indicating environmental influence quite apart from a wide placement in the tolerant to resistant continuum. Likewise, CNP is a trait highly influenced by environment, especially soil nitrogen and water. When there is high rainfall, CNP values tend to be low but high during the dry season for the same genotype.

In 2004/2005, the genotypes had mean FYLD >13.92 t/ha, mean DYLD >4.57 t/ha, mean DMC >4.57 t/ha, mean DMC >29.49%, mean gari yield >16.0%, mean Nostm25 >9, mean ESTAB > 60%, and mean starch content >60.8%. As in 2003/2004, the CVs of all the traits ranged between 4.92 and 15.72 except for CMDSI and CNP. The genotype with the highest FYLD across environments was 95/0289 (21.84 t/ha). The genotype with the highest DYLD was 96/1632 (9.29 t/ha), for DMC it was TME 419 (39.3%), for ESTAB it was 97/4779 (87%), for gari it was 96/1632 (34.0%), for Nostm25 it was 98/0505 (16.9), and for starch it was 92/0325 (73.9%).

In 2003/2004, Additive Main Effects and Multiplicative Interaction (AMMI) analysis (Gauch, 2002) was used to assess for genotype by environment interaction and select for stability. Since some data were missing, only 32 clones and 10–11 environments could participate in the analyses. The AMMI analysis was done for three variables, FYLD, DYLD, and DMC. The analysis of variance of the AMMI, Tables 10–12, for FYLD, DYLD, and DMC, show that the effect of genotype (G), environment (E), and genotype by environment interaction (GEI) were significant ($p<0.01$). For the three variables, the E effect was highest (52.3% for FYLD, 43.8% for DYLD, and 40.1% for DMC). The GEI effect accounted for the next high source of variation (31.5% for FYLD, 39.1% for DYLD, and 39.7% for DMC). The G effect accounted for 16.1% (FYLD), 17.1% (DYLD), and 20.1% (DMC). This large variability within GEI justifies the use of AMMI in explaining the pattern of GEI for the three traits for the genotypes.

The AMMI biplot for FYLD (Fig. 1) shows large variability among the genotypes and the environments. From the biplot, four sets of environments were distinguished: (i) Calabar, Warri, and Ibadan, with positive IPCA1 and mean performance below average, (ii) Umudike, with negative IPCA1 and mean performance below average, (iii) Ilorin, Egbema, Abuja, Kaduna, and Mokwa, with negative IPCA1 and above-average yields, and (iv) Ubiaja and Ikenne, with positive IPCA1 and above-average yields. The stable clones for FYLD were G14, G11, G24, G21, G25, G9, G4, G6, G17, G10, G18, G29, G26, G19, G31, G8, G27, G30, G28, G7, G1, and G2). The yields of G19, G31, G8, G27, G30, G28, G7, G1, and G2 were unfortunately below average. Genotype 92B/00061 had the highest FYLD. It performed best in the Ubiaja and Ikenne environment.

The AMMI biplot for DYLD (Fig. 2) shows also variability among the genotypes and the environments, although less dispersed than in the FYLD biplot (Fig. 1). From the biplot, four sets of environments were distinguished (i) Calabar, with positive IPCA1 and mean performance below average, (ii) Ibadan, with negative IPCA1 and mean performance below average, (iii) Abuja, Egbema, Kaduna, and Mokwa, with negative IPCA1 and above-average DYLD, and (iv) Ikenne, Ilorin, Ubiaja, and Warri, with positive IPCA1 and above-average DYLD. The stable genotypes were G9, G11, G14, G24, G16, G15, G25, G18, G21, G5, G29, G28, G10, G2, G26, G6, G3, G20, G17, G23, G8, G1, G19, G27, G30, G7, and G12. The DYLD of G19, G27, G30, G7, and G12 were below average. Genotype 96/1632 had the highest DYLD. It performed best in Abuja, Egbema, Kaduna, and Mokwa.

The AMMI biplot for DMC (Fig. 3) also showed variability among genotypes and environments. From the biplot, four sets of environment exist (i) Calabar, and Abuja, with positive IPCA1 and mean DMC below average, (ii) Ibadan and Mokwa, with negative IPPCA1 with mean DMC below average, (iii) Egbema, Ilorin, Kaduna, and Warri, with negative IPCA1 and above-average DMC, (iv) Ubiaja and Ikenne, with positive IPCA1 and above-average DMC. The stable clones for DMC were G16, G32, G7, G20, G29, G5, G9, G24, G2, G25, G1, G27, G15, G31, G8, G19, G22, G3, G13, G26, G17, and G4. The DMC of G27, G15, G31, G8, G19, G22, G3, G13, G26, G17, and G4 were below average. Genotype 96/1632 had the highest DMC and performed best in the Ubiaja and Ikenne environment.

For 2004/2005 data, GEI and stability were assessed using GGE Biplot (Yan, 2001). Figure 4 shows a biplot of all the genotypes (lines) and seven traits (testers). CMDSI (MCMD_NW) was found to be an outlier. This was because the 40 clones being screened seem to be well endowed with CMD tolerance to a high level. This trait was not variable, as would be expected. The variance in the trait was just for classification but did not translate into real susceptibility because the criterion for the inclusion of these genotypes in this trial was resistance/tolerance (<1.04 on severity scale 1–5). Due to this outlier effect, CMDSI and OTHDISSI_NW were eliminated in the biplot analysis. Figure 5 shows the new biplot with five traits which had a cumulative account of PC1 and PC2 of 82.5%, unlike 71.4% in Figure 4.

Results and Discussion

Data collection, analyses, ranking, and stepwise selections at OFT, DEMO, MLT, as well as integration of field and non-field (biochemical) characters resulted in a list of candidates nominated for release. Table 13 shows the summary of the stable genotypes based on these three traits (FYLD, DYLD, DMC) and the 16 genotypes that were eventually nominated for release in 2005 from the 2003/2004 trials. Genotypes TME 419, 92B/00068, 97/3200, and 98/0510 were not among the 32 genotypes that were included in the AMMI analysis but were included in the suggested list because of high gari and starch yield, as was evident during organoleptic and food tests with farmers. The other genotypes nominated were 91/02324, 92/0057, 92/0326, 92B/00061, 95/0289, 96/1632, 97/2205, 97/4763, 98/0505, 98/0581, 99/3073, and M98/0068. Genotypes 96/1642, 98/2101, and 98/2226 could have made the list but did not meet the agreed level for DMC. On 30 August 2005, based on the 2003/2004 data evaluation, TME 419, TMS 97/2205, TMS 98/0505, TMS 98/0510, and TMS 98/0581 were selected by the TSC on crop variety release, based on their acceptability for food, livestock feed, and industrial characteristics. The TSC approved the nominations and recommended them to the national VRC. The national VRC met on 1 September 2005 and favorably considered the five varieties as suitable for official release to Nigerian farmers.

For the 2004/2005 evaluation, the close association of genotypes to DYLD was taken as a key arbiter for priortizing the genotypes. This was to balance the needs of the farmers who favored some field variables, such as robust looking roots which command higher market prices, and the processors, who favor culinary, biochemical, and high DMC for meeting end-users food and industry requirements. In Figure 5, the close association of FYLD and DYLD is evident. Thus, the proximity of the genotypes to these variables was used as an indicator for selection. The nearest genotypes were 96/1632, 95/0289, 98/0581, M98/0068, 96/0523, 98/0510, 98/0505, 92B/00061, TME 419, and 99/3073. Genotypes 98/0581, 98/0510, 98/0505, and TME 419, though selected in 2004/2005 data evaluations, had already been released, based on 2003/2004 data analyses. Figure 6 shows the stability plot of the genotypes, based on a virtual environment across all the 32 locations. It also shows the proximity of the genotypes to DYLD and FYLD. The two most stable genotypes were 96/0523 and 98/0002. Genotype 96/1632 was the best genotype in terms of DYLD and FYLD because it was the nearest in the biplot to FYLD and DYLD. Genotypes 96/1632, 95/0289, 98/0581, M98/0068, 96/0523, 98/0510, 92B/00061, TME 419, 97/4779, 95/0166, 99/3073, and 96/1089A were, however, suggested to the TSC for release. The committee, having a maximum limit of release of 5 varieties in 2006, approved 96/1632, 98/0002, 92/0326, and 92/0057. Genotypes 92/0326 and 92/0057 were included by the TSC because of their 2003/2004 performance and because farmers had already adopted these genotypes in large numbers as extension agents reported in 2006.

Five varieties, approved by the TSC on 5 December 2006, were presented to the national VRC. This Committee approved the registration and release of the 5 varieties with effect from 7 December 2006. The 5 varieties were NR 87184, TMS 92/0057, TMS 92/0326, TMS 96/1632 and TMS 98/0002. Four of the 5 released lines originated with IITA; NR

87184 was a contribution from NRCRI, Umudike. To summarize, selection by index creation helped to integrate all the crop aspects that related to the interests of diverse stakeholders and components in the cassava commodity chain. By using two related indexed models, 2003/2004–MLTSI and 2004/2005–MLTSI, we were able to shortlist seven candidate genotypes concurrently. This suggests that the second year adjustment did not alter the efficacy of the general model and either approach will enable researchers to select appropriately. One would ask, what will be the impact of doing yield trials at five fewer sites; changing the time of year, deleting some of the diseases from consideration, etc. How do you know that your varietal selection will stand? The answer to this will require validating these models. This paper shows the logic in the steps justified by the concurrent genotypes selected by the two models. The farmers are using these materials and they are widely spreading. Adoption studies in about 5 years will provided further evidence on whether the varieties will stand.

Selecting with the hope of capturing the year-to-year variation is difficult and costly. It is more practical to capture the wide ecological variation that also includes the aspect of difference in moisture availability to cassava genotypes over a wide range of sites in a single year, provided the sites are large and the number of sites is representative of the relevant agroecologies. The number of sites previously being used to test the genotypes before their nomination for release was limited. The current work has covered more sites and is also ecologically more diverse than the earlier attempts by breeders to identify top elite genotypes. The cost of the wider coverage of the cassava geo-space in the country was borne by a group of donors. This made the work of implementation stakeholder-driven, rather than just the work of government agencies, as had happened for most of the 17 “earlier” cassava varieties released since 1985 in Nigeria.

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Table 1. Variables obtained from OFTs, and DEMOs.

Variables	Method	OFTs	DEMOs
Number of plants (NoStd)	Number of plants harvested in the four central rows.	1	1
Root weight	Total weight of fresh tubers from approved harvest area.	1	1
Weight of root suitable (RWSuit)	Weight of roots only suitablefor sale in local root market.	1	1
Weight of root unsuitable (RWUnsuit)	Weight of roots unsuitable for sale in local root market.	1	1
Number of 1 m long stems	Number of 1 m long stems that can be sold as planting material.		1
Plant formation	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Root weight	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Plantable stem weight	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Root flesh color	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Root shape	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Gari quantity	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Gari color	Visually assessed on a scale of 1–3, where 1 mweant disliked and 3 meant liked.	1	1
Gari taste	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Gari swelling	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Gari hand feel	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
Gari stickiness	Visually assessed on a scale of 1–3, where 1 meant disliked and 3 meant liked.	1	1
CMD incidence (CMDI)	Proportion of plants with disease symptoms to total number of plants in approved harvest area.		1
CMD severity (CMDS)	Severity scale 1–5, where 1=no disease and 5=severe damage.	1	

Table 2. Variables obtained from MLTs.

Variables	Method
Number of plants (NoStd)	Number of plants harvested in the four central rows.
Root weight	Total weight of fresh tubers from approved harvest area.
Weight of roots suitable (RWSuit)	Weight of roots only, suitable for sale in local root market.
Weight of roots unsuitable (RWUnsuit)	Weight of roots unsuitablefor sale in local root market.
Number of 1m long stems	Number of 1m long stems that can be sold as planting material.
Number of roots	Total count of all roots in approved harvest area.
Dry matter content (DMC)	Oven-dry 100 g of peeled roots and 100 g of peels at 80 C for 48 hrs or until dry and weigh.
Mealiness	Boil 2 cm thick peeled cylindrical roots for 25 mins in already boiling water. Press between fingers: Score: 0=waxy, 1=not mealy, 2=mealy, 3=very mealy.
Taste	For boiled samples only. Score 1=bitter, 2=bland, 3=sweet.
Fresh cortex color (CtCol_Frsh)	For fresh samples. Score 1=white, 2=cream, 3=yellow.
Boiled cortex color (CtCol_Boil)	For boiled samples. Score 1=white, 2=cream, 3=yellow.
Ease of peeling (Ease_peel) 2=easy, 3=very easy.	Peel 5–10 roots by hand, note ease when separating peel from the cortex. Score: 1=difficult,
Knife peel loss (KnfPeelLoss)	Use team of 3–5 peelers. Peel 10 kg of fresh roots. Weigh peels and weigh cortex.
Hand peel loss (CortPeel)	Weigh and hand peel the roots, weigh peel and roots separately.
Number of roots suitable (RtNoSuit)	Number of roots suitable for sale in local root market.
Number of roots unsuitable (RtNoUnsuit)	Number of root unsuitable for sale in local root market.
Weight of shoots (ShtWt)	Total weight of all aboveground materials from approved harvest area.
Plant height (PltHgt)	Average height of plants taken around the center of the plot (cm) at harvest.
Rot number (rotNo)	Total number of rotten roots from approved harvest area.
Plants with root rot (NoPltRot)	Number of plants showing root rots at harvest.
Standard stake yield (NOSTM25)	Total number of 25 cm stakes from all stems
Lodging (%Lodg)	Number of plants whose main stems are inclined more than 45 degrees from the vertical.
CMD incidence (CMDI)	Proportion of plants with disease symptoms to total number of plants in approved harvest area. CMDI was assessed at 1, 3, and 6 months after planting (MAP); CMDI1, CMDI3, CMDI6.
CMD severity (CMDS)	Severity scale 1–5, where 1=no disease and 5=severe damage. CMDS was assessed at 1, 3, and 6 MAP; CMDS1, CMDS3, CMDS6.
Cassava bacterial blight disease incidence (CBBI)	Proportion of plants with disease symptoms to total number of plants in approved harvest area. CBBI was assessed at 1, 3, and 6 MAP; CBBI1, CBBI3, CBBI6.
Cassava bacterial blight disease severity (CBBS)	Severity scale 1–5, where 1=no disease and 5=severe damage. CBBS was assessed at 1, 3, and 6 MAP; CBBS1, CBBS3, CBBS6. Cassava anthracnose disease incidence (CADI) Proportion of plants with disease symptoms to total number of plants in approved harvest area. CADI was assessed at 9 and 12 MAP; CADI9, CADI12.
Cassava anthracnose disease severity (CADS)	Severity scale 1–5, where 1=no disease and 5=severe damage. CADS was assessed at 9 and 12 MAP; CADS9, CADS12.
Cassava GM incidence (CGMI)	Proportion of plants with GM damage to total number of plants in approved harvest area. CGMI was assessed at 9 and 12 MAP; CGMI9, CGMI12.
Cassava GM severity (CGMS)	Severity scale 1–5, where 1=no GM damage and 5=severe damage. CGMS was assessed at 9 and 12 MAP; CGMS9, CGMS12.
Sprouting ability	Proportion of plants that have sprouted 4 weeks after planting.

Table 3. Key variables agreed to be used in final trial evaluations and selection by stakeholders.

Trials	Key traits for selection
OFTs and DEMOs	Farmers' assessment using variables such as root weight, plantable stem weight, *gari* quantity, plant formation, assessed on a scale of 1–3, and actual root yield measurements.
MLTs ability at harvest,	DYLD (DYLD), CMDSI, OTHDISSI, FYLD (FYLD), dry matter content (DMC), establishment standard stake yield (number of 25 cm stakes obtainable), root shape.
Accepted trials	Trials with greater than 75% expected data points.

Table 4. Data matrix for calculating an index for ranking genotypes based on farmers' assessment of root shape.

a	b	c	d	e	f	g	h	i
	Like it-3,	Indifferent -2, Do not like it -1		Total persons assessing each clone				
Genotypes	1	2	3		1	2	3	Index
4(2)1425	0	1	8	9	0.000	0.222	2.667	2.889
82/00058	0	0	10	10	0.000	0.000	3.000	3.000
91/02324	0	1	1	2	0.000	1.000	1.500	2.500
92/0057	0	1	1	2	0.000	1.000	1.500	2.500
92/0067	0	1	0	1	0.000	2.000	0.000	2.000
92/0325	0	1	11	12	0.000	0.167	2.750	2.917
92/0326	0	0	2	2	0.000	0.000	3.000	3.000
92B/00061	0	0	1	1	0.000	0.000	3.000	3.000
92B/00068	0	0	1	1	0.000	0.000	3.000	3.000
94/0026	0	0	15	15	0.000	0.000	3.000	3.000
96/0603	0	0	1	1	0.000	0.000	3.000	3.000
96/1025	0	0	1	1	0.000	0.000	3.000	3.000

Notes

Column	Descriptor
a	List of all genotypes.
b	Count of number of farmers that assessed a genotype as 1 (do not like).
c	Count of number of farmers that assessed a genotype as 2 (indifferent).
d	Count of number of farmers that assessed a genotype as 3 (liked).
e	Sum of columns a, b, and c. Total number of farmers who assessed the genotype.
f	Product of counts in column b and score 1 divided by the total number of farmers in column e.
g	Product of counts in column c and score 2 divided by the total number of farmers in column e.
h	Product of counts in column d and score 3 divided by the total number of farmers in column e.
i	Sum of columns f, g, and h. The new index ranging from 1 to 3

Table 5. An example of a combination of frequency and rank sum methods in the combination of OFT select and DEMO select lists to produce a single index.

Lists	Rank	OFT select	Combined clone list	A Freq	B OFT	C DEMO	D DEMO2	E rank sum	F mean	G inverse	H prop	I product	J index
1	1	98/2101	95/0289	2	3	1	0.50	3.50	1.75	0.57	1.00	0.57	57.14
1	2	92/0057	97/0162	1		2	1.00	1.00	1.00	1.00	0.50	0.50	50.00
1	3	95/0289	98/2101	2	1	9	4.50	5.50	2.75	0.36	1.00	0.36	36.36
1	4	97/0211	94/0026	1		3	1.50	1.50	1.50	0.67	0.50	0.33	33.33
1	5	92/0326	96/1632	1		3	1.50	1.50	1.50	0.67	0.50	0.33	33.33
1	6	98/0002	97/2205	1		3	1.50	1.50	1.50	0.67	0.50	0.33	33.33
1	7	92/0325	98/0002	2	6	3	1.50	7.50	3.75	0.27	1.00	0.27	26.67
1	8	98/0505	92/0057	1	2		0.00	2.00	2.00	0.50	0.50	0.25	25.00
1	9	TME419	98/0505	2	8	10	5.00	13.00	6.50	0.15	1.00	0.15	15.38
1	10	92B/00061	TME419	2	9	3	1.50	10.50	5.25	0.19	1.00	0.19	19.05
			96/1642	1		8	4.00	4.00	4.00	0.25	0.50	0.13	12.50
	Rank	Demo select	97/0211	1	4		0.00	4.00	4.00	0.25	0.50	0.13	12.50
2	1	95/0289	92/0326	1	5		0.00	5.00	5.00	0.20	0.50	0.10	10.00
2	2	97/0162	92/0325	1	7		0.00	7.00	7.00	0.14	0.50	0.07	7.14
2	3	98/0002	92B/00061	1	10		0.00	10.00	10.00	0.10	0.50	0.05	5.00
2	3	97/2205											
2	3	96/1632											
2	3	94/0026											
2	3	TME419											
2	8	96/1642											
2	9	98/2101											
2	10	98/0505											

Table 6. Data matrix for calculating an index for ranking genotypes based on each trait in 2005/2006 evaluation.

		Untransformed							Transformed						
Obs	Clone	mcmd	fyld	dyld	othdissi	dm	Estab	nostm25	mcmd _nw	fyld _nw	dyld _nw	othdissi _nw	dm _nw	Estab _nw	nostm25 _nw
1	4(2)1425	0.12	16.80	6.61	0.28	36.06	0.70	9.53	0.928	0.769	0.712	0.551	0.917	0.799	0.565
2	82/00058	0.05	19.23	6.45	0.36	32.62	0.76	13.45	0.343	0.881	0.695	0.712	0.829	0.865	0.797
3	91/02324	0.01	19.30	7.05	0.30	34.47	0.77	10.64	0.057	0.883	0.759	0.600	0.876	0.881	0.631
4	92/0057	0.02	15.63	6.43	0.32	38.72	0.78	12.31	0.115	0.716	0.692	0.625	0.985	0.891	0.730
5	92/0067	0.02	15.81	5.82	0.28	35.72	0.77	13.64	0.130	0.724	0.627	0.548	0.908	0.881	0.809
6	92/0325	0.03	13.92	5.99	0.32	38.25	0.75	15.05	0.257	0.637	0.645	0.626	0.973	0.859	0.892
7	92/0326	0.06	20.24	6.88	0.28	34.50	0.78	10.96	0.461	0.927	0.741	0.549	0.877	0.893	0.650
8	92B/00061	0.03	19.05	7.63	0.25	36.06	0.82	12.09	0.230	0.872	0.822	0.489	0.917	0.935	0.717
9	92B/00068	0.02	20.79	6.59	0.26	34.72	0.76	11.42	0.117	0.952	0.710	0.511	0.883	0.868	0.677
10	94/0026	0.02	17.44	5.91	0.29	33.83	0.71	14.03	0.176	0.798	0.637	0.578	0.860	0.816	0.832
11	94/0039	0.02	17.31	6.28	0.27	34.45	0.76	12.40	0.135	0.792	0.676	0.537	0.876	0.875	0.735
12	94/0561	0.13	15.67	4.57	0.27	29.49	0.75	12.81	1.000	0.717	0.492	0.543	0.750	0.856	0.760
13	95/0166	0.02	21.21	7.14	0.28	32.90	0.77	16.46	0.181	0.971	0.769	0.553	0.836	0.879	0.976
14	95/0289	0.03	21.84	7.57	0.31	33.62	0.82	13.10	0.191	1.000	0.815	0.618	0.855	0.937	0.776
15	95/0379	0.02	14.87	5.65	0.30	33.16	0.75	15.89	0.144	0.681	0.609	0.602	0.843	0.855	0.942
16	96/0523	0.01	19.78	7.59	0.27	33.66	0.84	13.55	0.064	0.906	0.817	0.534	0.856	0.966	0.803
17	96/0603	0.01	19.59	6.62	0.29	33.15	0.82	12.81	0.070	0.897	0.713	0.580	0.843	0.934	0.759
18	96/1089A	0.01	20.67	7.78	0.31	36.19	0.77	15.52	0.055	0.946	0.838	0.615	0.920	0.879	0.920
19	96/1565	0.00	20.33	6.79	0.34	33.26	0.77	13.52	0.009	0.931	0.731	0.670	0.846	0.884	0.802
20	96/1569	0.00	20.19	7.50	0.42	36.64	0.80	10.75	0.018	0.924	0.808	0.831	0.932	0.918	0.637
21	96/1632	0.01	21.59	9.29	0.25	38.89	0.82	13.32	0.049	0.988	1.000	0.503	0.989	0.940	0.789
22	96/1642	0.01	17.39	6.04	0.34	32.40	0.80	13.23	0.062	0.796	0.651	0.682	0.824	0.917	0.784
23	97/0162	0.01	18.17	6.33	0.32	35.71	0.80	9.72	0.109	0.832	0.682	0.629	0.908	0.914	0.576
24	97/0211	0.01	15.49	6.16	0.51	35.69	0.79	13.36	0.089	0.709	0.663	1.000	0.907	0.906	0.792
25	97/2205	0.01	15.44	6.27	0.28	38.48	0.83	16.62	0.095	0.707	0.675	0.563	0.978	0.951	0.985
26	97/3200	0.01	16.58	5.64	0.24	32.30	0.77	13.35	0.054	0.759	0.607	0.484	0.821	0.886	0.792
27	97/4763	0.01	20.99	8.26	0.29	35.20	0.85	16.14	0.049	0.961	0.889	0.574	0.895	0.975	0.957
28	97/4769	0.01	18.31	6.61	0.30	33.07	0.81	11.86	0.102	0.838	0.711	0.592	0.841	0.933	0.703
29	97/4779	0.01	20.27	8.51	0.28	32.15	0.87	14.67	0.052	0.928	0.916	0.544	0.817	1.000	0.870
30	98/0002	0.02	20.90	6.97	0.26	34.23	0.82	14.84	0.119	0.957	0.751	0.509	0.870	0.937	0.880
31	98/0505	0.01	20.54	7.61	0.27	34.86	0.84	16.87	0.052	0.940	0.819	0.529	0.886	0.965	1.000
32	98/0510	0.02	20.01	7.48	0.28	35.45	0.69	13.18	0.123	0.916	0.806	0.551	0.901	0.791	0.781
33	98/0581	0.01	21.17	7.81	0.29	35.31	0.84	13.38	0.050	0.969	0.841	0.566	0.898	0.959	0.793
34	98/2101	0.01	20.68	6.95	0.28	33.29	0.82	13.63	0.061	0.946	0.749	0.557	0.846	0.939	0.808
35	98/2226	0.01	16.07	6.38	0.28	35.00	0.76	14.12	0.057	0.736	0.687	0.548	0.890	0.868	0.837
36	99/2123	0.01	17.58	6.78	0.28	37.92	0.76	12.60	0.049	0.805	0.730	0.550	0.964	0.871	0.747
37	99/3073	0.01	20.12	7.69	0.24	35.54	0.79	11.07	0.099	0.921	0.829	0.467	0.904	0.907	0.656
38	99/6012	0.06	16.75	6.35	0.34	33.18	0.72	10.32	0.426	0.767	0.684	0.664	0.844	0.828	0.612
39	M98/0028	0.02	15.58	6.37	0.29	38.42	0.79	9.61	0.126	0.713	0.686	0.575	0.977	0.906	0.569
40	M98/0040	0.01	16.19	6.72	0.29	36.93	0.73	10.58	0.057	0.741	0.724	0.577	0.939	0.833	0.627
41	M98/0068	0.01	21.43	8.81	0.31	38.14	0.81	15.07	0.053	0.981	0.948	0.612	0.970	0.928	0.893
42	TME419	0.02	18.16	7.69	0.29	39.33	0.80	11.77	0.153	0.831	0.828	0.580	1.000	0.913	0.697
43	TMS30572	0.08	18.02	6.15	0.29	35.45	0.76	15.93	0.572	0.825	0.662	0.574	0.901	0.866	0.944
Maximum		0.1	21.8	9.3	0.5	39.3	0.9	16.9							

Table 7. Data matrix for calculating an index for ranking genotypes based on MLTSI in 2005/2006 evaluation.

									All		All except cmd		All except all diseases	
SN	Clone	cmd-index	fyld	dyld	othdissi	dm	Estab	nostm25	Index	Rank	Index	Rank	Index	Rank
21	96/1632	0.0489	0.9884	1.0000	0.5034	0.9888	0.9395	0.7894	4.29	3	1.56	1	1.48	1
41	M98/0068	0.0529	0.9809	0.9484	0.6119	0.9696	0.9276	0.8932	4.01	9	1.50	2	1.47	2
27	97/4763	0.0489	0.9609	0.8895	0.5741	0.8948	0.9746	0.9567	4.23	4	1.49	4	1.44	3
31	98/0505	0.0517	0.9403	0.8195	0.5291	0.8862	0.9651	1.0000	4.07	7	1.49	3	1.41	4
29	97/4779	0.0520	0.9280	0.9161	0.5441	0.8174	1.0000	0.8699	4.03	8	1.47	5	1.40	5
18	96/1089A	0.0546	0.9462	0.8378	0.6147	0.9201	0.8790	0.9203	3.87	10	1.43	12	1.39	6
33	98/0581	0.0501	0.9692	0.8411	0.5661	0.8977	0.9585	0.7932	4.12	6	1.45	8	1.39	7
14	95/0289	0.1909	1.0000	0.8151	0.6185	0.8547	0.9367	0.7763	1.96	34	1.41	13	1.36	8
13	95/0166	0.1806	0.9712	0.7692	0.5528	0.8365	0.8791	0.9760	2.03	33	1.43	11	1.36	9
30	98/0002	0.1193	0.9567	0.7508	0.5088	0.8702	0.9371	0.8795	2.46	23	1.45	7	1.35	10
16	96/0523	0.0640	0.9056	0.8173	0.5337	0.8558	0.9659	0.8032	3.48	16	1.43	10	1.35	11
42	TME419	0.1531	0.8314	0.8276	0.5797	1.0000	0.9134	0.6975	2.15	31	1.40	15	1.34	12
8	92B/00061	0.2303	0.8721	0.8220	0.4892	0.9167	0.9352	0.7169	1.87	36	1.45	9	1.33	13
20	96/1569	0.0175	0.9243	0.8075	0.8310	0.9316	0.9181	0.6371	9.34	2	1.31	30	1.33	14
37	99/3073	0.0986	0.9210	0.8286	0.4670	0.9037	0.9068	0.6563	2.72	19	1.46	6	1.33	15
34	98/2101	0.0610	0.9465	0.7487	0.5568	0.8463	0.9387	0.8082	3.57	15	1.40	14	1.33	16
32	98/0510	0.1230	0.9159	0.8056	0.5510	0.9013	0.7912	0.7812	2.37	27	1.39	16	1.31	17
25	97/2205	0.0955	0.7067	0.6751	0.5626	0.9784	0.9515	0.9853	2.70	20	1.38	18	1.30	18
19	96/1565	0.0091	0.9307	0.7311	0.6699	0.8456	0.8842	0.8015	16.92	1	1.33	27	1.30	19
17	96/0603	0.0704	0.8966	0.7127	0.5803	0.8429	0.9339	0.7593	3.21	18	1.36	22	1.28	20
7	92/0326	0.4610	0.9267	0.7407	0.5492	0.8772	0.8925	0.6500	1.49	39	1.37	19	1.28	21
36	99/2123	0.0489	0.8048	0.7304	0.5503	0.9640	0.8707	0.7467	4.12	5	1.37	20	1.28	22
43	TMS30572	0.5718	0.8250	0.6620	0.5736	0.9013	0.8663	0.9443	1.42	40	1.36	21	1.28	23
9	92B/00068	0.1169	0.9517	0.7095	0.5109	0.8827	0.8683	0.6772	2.43	25	1.39	17	1.28	24
3	91/02324	0.0571	0.8834	0.7587	0.6003	0.8765	0.8811	0.6307	3.67	13	1.33	23	1.27	25
2	82/00058	0.3428	0.8805	0.6948	0.7124	0.8294	0.8652	0.7972	1.52	38	1.28	38	1.25	26
28	97/4769	0.1017	0.8382	0.7113	0.5917	0.8408	0.9327	0.7029	2.55	22	1.32	28	1.25	27
4	92/0057	0.1148	0.7156	0.6919	0.6250	0.9845	0.8914	0.7295	2.38	26	1.30	31	1.25	28
35	98/2226	0.0567	0.7356	0.6867	0.5483	0.8898	0.8682	0.8368	3.68	12	1.33	24	1.23	29
23	97/0162	0.1086	0.8317	0.6819	0.6288	0.9079	0.9140	0.5763	2.43	24	1.29	36	1.23	30
11	94/0039	0.1352	0.7923	0.6762	0.5367	0.8760	0.8749	0.7350	2.21	30	1.33	25	1.22	31
6	92/0325	0.2570	0.6374	0.6453	0.6265	0.9726	0.8593	0.8922	1.66	37	1.28	37	1.22	32
24	97/0211	0.0892	0.7090	0.6631	1.0000	0.9074	0.9060	0.7919	2.63	21	1.19	43	1.22	33
22	96/1642	0.0622	0.7962	0.6509	0.6819	0.8238	0.9168	0.7845	3.40	17	1.26	40	1.22	34
40	M98/0040	0.0567	0.7412	0.7238	0.5770	0.9389	0.8325	0.6274	3.66	14	1.30	32	1.21	35
5	92/0067	0.1300	0.7240	0.6268	0.5475	0.9081	0.8808	0.8088	2.24	29	1.31	29	1.21	36
39	M98/0028	0.1255	0.7130	0.6857	0.5750	0.9768	0.9060	0.5694	2.26	28	1.30	33	1.21	37
10	94/0026	0.1762	0.7984	0.6367	0.5783	0.8602	0.8161	0.8316	1.93	35	1.30	34	1.21	38
1	4(2)1425	0.9277	0.7690	0.7117	0.5513	0.9167	0.7986	0.5648	1.26	42	1.29	35	1.19	39
15	95/0379	0.1438	0.6806	0.6089	0.6020	0.8431	0.8546	0.9422	2.09	32	1.27	39	1.19	40
26	97/3200	0.0536	0.7590	0.6068	0.4841	0.8213	0.8860	0.7916	3.83	11	1.33	26	1.18	41
38	99/6012	0.4261	0.7670	0.6840	0.6642	0.8435	0.8279	0.6120	1.39	41	1.22	41	1.17	42
12	94/0561	1.0000	0.7173	0.4925	0.5427	0.7497	0.8555	0.7596	1.18	43	1.21	42	1.09	43

Clones in bold were among the top five released from 2004/2005 selection; Clones in bold italics are check varieties included in trials.

Table 8. Attributes of 40 new genotypes and three check varieties averaged over 18 MLTs in 2003/2004 season in Nigeria.

Clone	CMDSI	FYLD	DYLD	DMC	No1mstm	RTSHPSI	Gari	Starch	CNP
4(2)1425	0.85	13.77	5.28	36.17	19.08	4.08	18.41	75.74	7.52
82/00058	0.49	16.79	5.88	32.83	28.91	4.08	20.78	74.86	20.90
91/02324	0.10	19.11	6.53	32.67	34.14	3.83	14.37	72.38	14.58
92/0057	0.15	15.94	6.30	37.06	37.52	3.80	15.92	80.92	13.32
92/0067	0.28	17.35	6.08	34.73	39.26	4.16	19.14	70.71	11.97
92/0325	0.33	11.20	4.41	38.94	35.13	3.82	17.24	75.51	6.79
92/0326	0.64	15.28	5.58	34.42	35.84	3.77	15.41	75.00	6.80
92B/00061	0.38	21.90	7.96	35.46	36.56	4.39	19.32	77.43	11.30
92B/00068	0.29	18.45	6.28	32.61	32.91	4.37	19.76	83.80	11.34
94/0026	0.14	16.64	5.61	32.24	35.93	3.87	14.31	88.90	8.92
94/0039	0.19	18.78	6.93	35.77	36.12	3.90	16.57	78.95	7.22
94/0561	0.70	15.61	4.95	29.72	35.98	3.97	17.70	80.52	18.34
95/0166	0.26	19.05	6.71	33.66	43.89	4.03	15.60	74.07	7.41
95/0289	0.43	21.38	7.46	34.08	38.04	4.06	21.12	78.49	12.12
95/0379	0.20	16.23	5.76	34.74	35.33	3.92	17.75	78.72	9.49
96/0523	0.14	17.46	5.68	30.57	37.66	3.58	14.29	78.79	14.98
96/0603	0.19	18.77	6.49	33.90	35.53	3.95	16.91	69.14	13.51
96/1089A	0.12	16.37	5.75	35.56	26.09	3.58	22.92	76.75	11.67
96/1565	0.07	12.14	3.80	30.89	16.80	3.55	13.46		8.38
96/1569	0.02	15.32	6.80	39.15	33.14	3.78	16.00	81.88	13.25
96/1632	0.20	19.20	7.91	40.35	28.11	4.18	14.82	75.87	15.27
96/1642	0.14	19.01	6.85	34.28	39.44	3.83	17.31	76.43	10.39
97/0162	0.19	18.42	6.44	33.91	41.19	4.03	12.02	74.34	10.56
97/0211	0.07	15.60	5.12	33.12	23.57	3.86	17.56	77.97	13.78
97/2205	0.01	17.64	6.99	37.97	37.46	3.27	14.75	80.09	9.50
97/3200	0.00	15.02	4.89	31.74	22.90	3.58	19.03	81.56	14.82
97/4763	0.07	18.99	6.71	34.22	33.58	3.38	16.96	76.49	13.80
97/4769	0.11	14.86	4.53	31.64	29.36	3.81	22.66	69.38	9.55
97/4779	0.08	18.54	5.80	30.04	35.51	3.88	12.61	75.95	20.88
98/0002	0.10	17.31	6.57	35.46	33.48	4.01	24.38	73.06	9.68
98/0505	0.12	19.81	7.31	35.32	35.40	3.89	16.94	71.95	7.74
98/0510	0.14	15.47	5.33	34.26	28.28	4.31	18.22	79.87	10.99
98/0581	0.09	19.07	6.97	35.40	36.38	4.01	16.10	78.25	11.47
98/2101	0.16	16.56	6.14	34.77	40.77	3.66	15.46	76.22	5.35
98/2226	0.11	14.61	4.77	31.88	35.19	3.59	15.76	80.12	8.79
99/2123	0.08	12.94	5.02	36.58	29.40	3.20	18.74	70.91	8.25
99/3073	0.09	17.18	6.38	35.80	25.73	4.00	21.65	74.34	11.54
99/6012	0.74	13.10	3.73	29.34	36.24	3.50	18.29	74.73	12.71
M98/0028	0.21	14.04	5.06	34.58	28.63	3.79	14.43	71.38	11.85
M98/0040	0.18	15.71	5.40	33.81	29.68	3.84	21.23	76.13	11.75
M98/0068	0.08	17.89	6.91	38.01	25.44	3.49	17.66	75.85	9.85
TME419	0.27	16.98	6.56	37.59	36.39	4.01	25.01	77.11	11.01
TMS30572	0.62	13.59	5.31	36.32	30.46	3.59	18.18	71.88	12.47
Mean	0.23	16.72	5.98	34.46	32.94	3.84	17.60	76.49	11.44
SE	0.03	0.36	0.15	0.39	0.90	0.04	0.46	0.62	0.52
CV	90.64	14.24	16.83	7.41	17.91	7.03	17.10	5.22	30.04
Max	0.85	21.90	7.96	40.35	43.89	4.39	25.01	88.90	20.90
Min	0.00	11.20	3.73	29.34	16.80	3.20	12.02	69.14	5.35

FYLD: fresh root yield (t/ha); DMC: dry matter content of roots (%); DYLD: dry root yield (t/ha); CMDSI: CMD index; Starch: starch yield (starch weight as % of fresh unpeeled root yield); CNP: hydrocyanic acid potential in processed products (mg/100g); No1mstm: standard bundle length (number of one meter stems from plant); Gari: *gari* yield (%); RTSHPSI; root shape and size index.

Table 9. Attributes of 40 new genotypes and three check varieties averaged over 32 MLTs in 2004/2005 season in Nigeria.

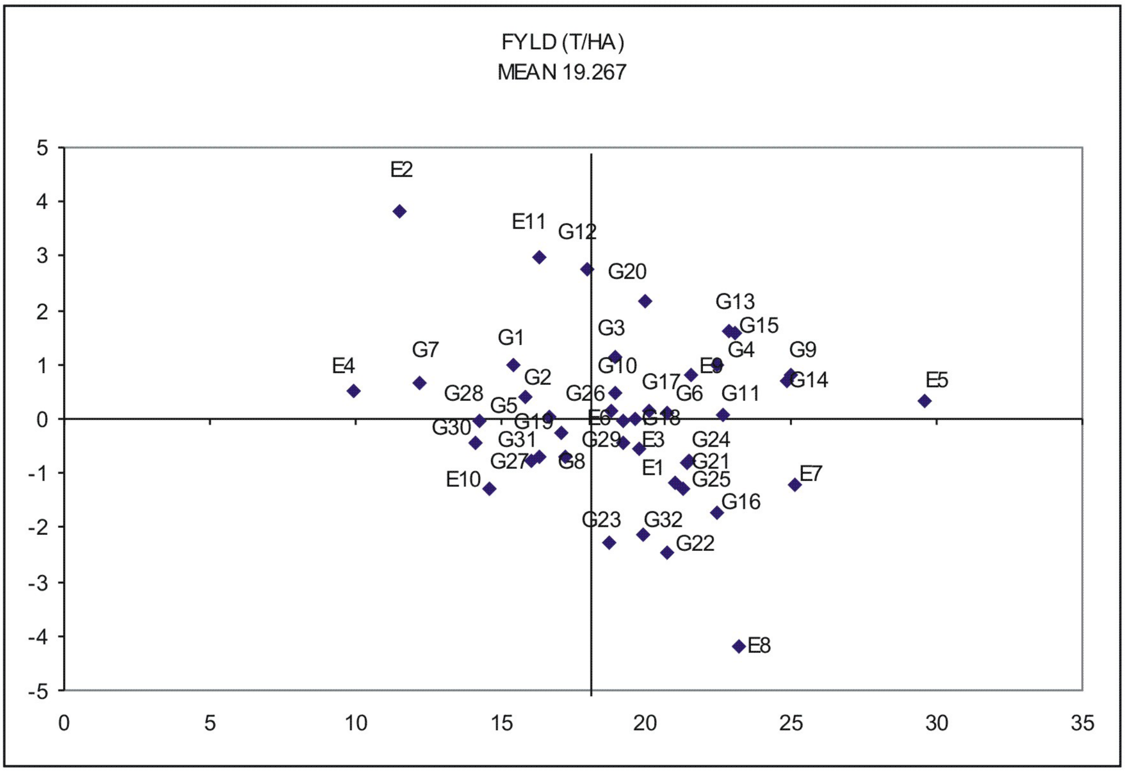
Clone	CMDSI	OTHDISSI	FYLD	DYLD	DMC	ESTAB	Gari	Nostm25	CNP	Starch
4(2)1425	0.12	0.28	16.80	6.61	36.06	0.70	24.00	9.53	7.18	69.89
82/00058	0.05	0.36	19.23	6.45	32.62	0.76	26.00	13.45	17.44	67.97
91/02324	0.01	0.30	19.30	7.05	34.47	0.77	23.40	10.64	13.41	69.75
92/0057	0.02	0.32	15.63	6.43	38.72	0.78	26.00	12.31	8.24	69.65
92/0067	0.02	0.28	15.81	5.82	35.72	0.77	26.40	13.64	9.96	62.68
92/0325	0.03	0.32	13.92	5.99	38.25	0.75	.	15.05	6.40	73.93
92/0326	0.06	0.28	20.24	6.88	34.50	0.78	.	10.96	9.13	69.35
92B/00061	0.03	0.25	19.05	7.63	36.06	0.82	22.00	12.09	6.40	67.17
92B/00068	0.02	0.26	20.79	6.59	34.72	0.76	27.20	11.42	11.42	63.52
94/0026	0.02	0.29	17.44	5.91	33.83	0.71	25.20	14.03	7.04	65.12
94/0039	0.02	0.27	17.31	6.28	34.45	0.76	23.60	12.40	8.31	67.01
94/0561	0.13	0.27	15.67	4.57	29.49	0.75	.	12.81	15.89	62.07
95/0166	0.02	0.28	21.21	7.14	32.90	0.77	22.40	16.46	5.48	63.42
95/0289	0.03	0.31	21.84	7.57	33.62	0.82	23.40	13.10	8.74	65.88
95/0379	0.02	0.30	14.87	5.65	33.16	0.75	.	15.89	10.62	72.90
96/0523	0.01	0.27	19.78	7.59	33.66	0.84	22.40	13.55	18.02	70.50
96/0603	0.01	0.29	19.59	6.62	33.15	0.82	24.00	12.81	14.13	65.94
96/1089A	0.01	0.31	20.67	7.78	36.19	0.77	.	15.52	7.94	70.55
96/1565	0.00	0.34	20.33	6.79	33.26	0.77	.	13.52	11.89	67.42
96/1569	0.00	0.42	20.19	7.50	36.64	0.80	.	10.75	8.28	69.72
96/1632	0.01	0.25	21.59	9.29	38.89	0.82	34.00	13.32	13.73	60.80
96/1642	0.01	0.34	17.39	6.04	32.40	0.80	24.00	13.23	7.74	65.14
97/0162	0.01	0.32	18.17	6.33	35.71	0.80	.	9.72	16.57	64.06
97/0211	0.01	0.51	15.49	6.16	35.69	0.79	.	13.36	11.40	73.50
97/2205	0.01	0.28	15.44	6.27	38.48	0.83	25.60	16.62	8.44	64.82
97/3200	0.01	0.24	16.58	5.64	32.30	0.77	22.80	13.35	10.56	68.36
97/4763	0.01	0.29	20.99	8.26	35.20	0.85	16.00	16.14	15.75	71.84
97/4769	0.01	0.30	18.31	6.61	33.07	0.81	.	11.86	11.16	70.74
97/4779	0.01	0.28	20.27	8.51	32.15	0.87	18.00	14.67	27.87	68.95
98/0002	0.02	0.26	20.90	6.97	34.23	0.82	24.00	14.84	6.89	73.80
98/0505	0.01	0.27	20.54	7.61	34.86	0.84	20.20	16.87	9.68	64.42
98/0510	0.02	0.28	20.01	7.48	35.45	0.69	.	13.18	13.92	71.18
98/0581	0.01	0.29	21.17	7.81	35.31	0.84	24.00	13.38	4.69	69.62
98/2101	0.01	0.28	20.68	6.95	33.29	0.82	26.00	13.63	2.89	68.41
98/2226	0.01	0.28	16.07	6.38	35.00	0.76	23.00	14.12	13.44	69.26
99/2123	0.01	0.28	17.58	6.78	37.92	0.76	24.00	12.60	8.88	65.96
99/3073	0.01	0.24	20.12	7.69	35.54	0.79	22.00	11.07	8.52	66.29
99/6012	0.06	0.34	16.75	6.35	33.18	0.72	20.40	10.32	24.77	68.59
M98/0028	0.02	0.29	15.58	6.37	38.42	0.79	24.80	9.61	14.73	61.93
M98/0040	0.01	0.29	16.19	6.72	36.93	0.73	.	10.58	11.29	65.24
M98/0068	0.01	0.31	21.43	8.81	38.14	0.81	25.60	15.07	7.29	65.59
TME419	0.02	0.29	18.16	7.69	39.33	0.80	20.00	11.77	6.54	66.64
TMS30572	0.08	0.29	18.02	6.15	35.45	0.76	30.00	15.93	10.42	66.15
Mean	0.02	0.30	18.54	6.88	35.08	0.78	23.88	13.14	11.00	67.58
SE	0.00	0.01	0.34	0.14	0.33	0.01	0.60	0.30	0.75	0.51
CV	117.10	15.72	11.97	13.38	6.25	5.21	13.90	15.06	44.92	4.92
Max	0.13	0.51	21.84	9.29	39.33	0.87	34.00	16.87	27.87	73.93
Min	0.00	0.24	13.92	4.57	29.49	0.69	16.00	9.53	2.89	60.80

FYLD: fresh root yield (t/ha); DMC: dry matter content of roots (%); DYLD: dry root yield (t/ha]; CMDSI: CMD index; OTHDISSI: other diseases index; Starch: starch yield (starch weight as % of fresh unpeeled root yield); CNP: hydrocyanic acid potential in processed products (mg/100g); Nostm25: standard stake yield (number of 20-25 cm stakes); ESTAB: establishment and survival ability (number of harvested stands as a proportion of the number planted); *Gari*: gari yield (%).

Table 10: AMMI analysis for the fresh root yield (t/ha) of 32 cassava genotypes evaluated in 11 environments in Nigeria.

Source	df	SS	MS	Probability
Total	1407	113642.32929	80.76925	
TRT	351	83556.65947	238.05316	0.0000000 ***
GEN	31	13454.23431	434.00756	0.0000000 ***
ENV	10	43741.82570	4374.18257	0.0000000 ***
G X E	310	26360.59947	85.03419	0.0000000 ***
IPCA 1	40	8777.82993	219.44575	0.0000000 ***
IPCA 2	38	4856.95070	127.81449	0.0000000 ***
IPCA 3	36	3183.25294	88.42369	0.0000000 ***
IPCA 4	34	2215.35088	65.15738	0.0000466 ***
IPCA 5	32	2141.85645	66.93301	0.0000407 ***
IPCA 6	30	1515.49184	50.51639	0.0066447 **
IPCA 7	28	1234.53044	44.09037	0.0350592 *
Residual	72	2435.33630	33.82412	0.1426924
Error	1056	30085.66981	28.49022	

n = 1408; Grand mean 19.267 t/ha
*, **, ***, Significant at p<0.05, p<0.01, p<0.001, NS= and Not Significant at p<0.05
IPCAi = Interaction Principal Component Axis i



GENOTYPE

G1 = 30572	G2 = 4(2)1425	G3 = 82/00058	G4 = 91/02324	G5 = 92/0057	G6 = 92/0067
G7 = 92/0325	G8 = 92/0326	G9 = 92B/00061	G10 = 94/0026	G11 = 94/0039	G12 = 94/0561
G13 = 95/0166	G14 = 95/0289	G15 = 96/0603	G16 = 96/1632	G17 = 96/1642	G18 = 97/0162
G19 = 97/0211	G20 = 97/2205	G21 = 97/4763	G22 = 97/4779	G23 = 98/0002	G24 = 98/0505
G25 = 98/0581	G26 = 98/2101	G27 = 98/2226	G28 = 99/2123	G29 = 99/3073	G30 = 99/6012
G31 = M98/0040	G32 = M98/0068				

ENVIRONMENT

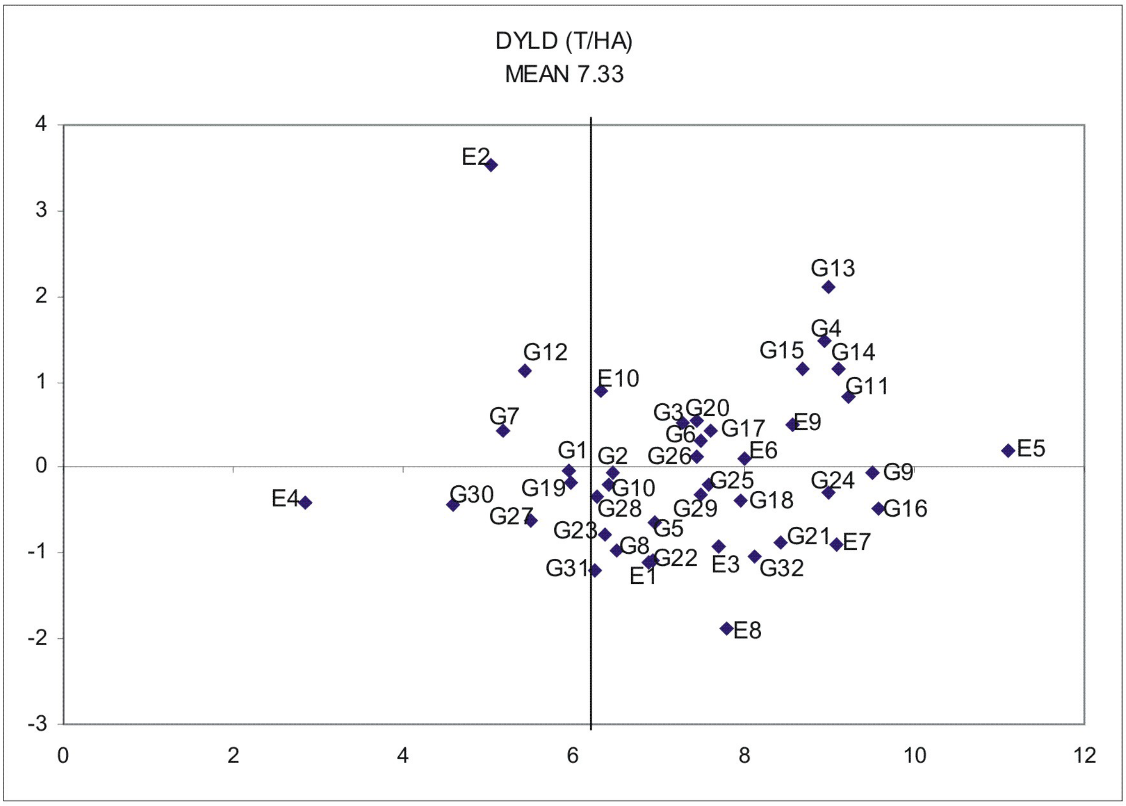
E1 = Abuja	E2 = Calabar	E3 = Egbema	E4 = Ibadan	E5 = Ikenne	E6 = Ilorin
E7 = Kaduna	E8 = Mokwa	E9 = Ubiaja	E10 = Umudike	E11 = Warri	

Figure 1. AMMI biplot for fresh root yield (t/ha) of 32 cassava genotypes evaluated in 11 environments in Nigeria.

Table 11: AMMI analysis for the dry root yield (t/ha) of 32 cassava genotypes evaluated in 10 environments in Nigeria.

Source	df	SS	MS	Probability
Total	639	8058.95329	12.61182	
TRT	319	6781.38455	21.25826	0.0000000 ***
GEN	31	1162.24138	37.49166	0.0000000 ***
ENV	9	2970.02327	330.00259	0.0000000 ***
G X E	279	2649.11990	9.49505	0.0000000 ***
IPCA 1	39	809.08882	20.74587	0.0000000 ***
IPCA 2	37	551.05496	14.89338	0.0000000 ***
IPCA 3	35	461.54239	13.18693	0.0000000 ***
IPCA 4	33	241.43581	7.31624	0.0045694 **
IPCA 5	31	222.06064	7.16325	0.0071719 **
IPCA 6	29	139.04207	4.79455	0.2238491
IPCA 7	27	117.28105	4.34374	0.3519020
Residual	48	107.61416	2.24196	0.9917132
Error	320	1277.56874	3.99240	

n = 640; Grand mean 7.33 t/ha
*, **, ***, Ns Significant at p<0.05, p<0.01, p<0.001 and Not Significant at p<0.05
IPCAi = Interaction Principal Component Axis i



GENOTYPE

G1 = 30572	G2 = 4(2)1425	G3 = 82/00058	G4 = 91/02324	G5 = 92/0057	G6 = 92/0067
G7 = 92/0325	G8 = 92/0326	G9 = 92B/00061	G10 = 94/0026	G11 = 94/0039	G12 = 94/0561
G13 = 95/0166	G14 = 95/0289	G15 = 96/0603	G16 = 96/1632	G17 = 96/1642	G18 = 97/0162
G19 = 97/0211	G20 = 97/2205	G21 = 97/4763	G22 = 97/4779	G23 = 98/0002	G24 = 98/0505
G25 = 98/0581	G26 = 98/2101	G27 = 98/2226	G28 = 99/2123	G29 = 99/3073	G30 = 99/6012
G31 = M98/0040	G32 = M98/0068				

ENVIRONMENT

E1 = Abuja	E2 = Calabar	E3 = Egbema	E4 = Ibadan	E5 = Ikenne
E6 = Ilorin	E7 = Kaduna	E8 = Mokwa	E9 = Ubiaja	E10 = Warri

Figure 2. AMMI biplot for dry root yield (t/ha) of 32 cassava genotypes evaluated in 10 environments in Nigeria.

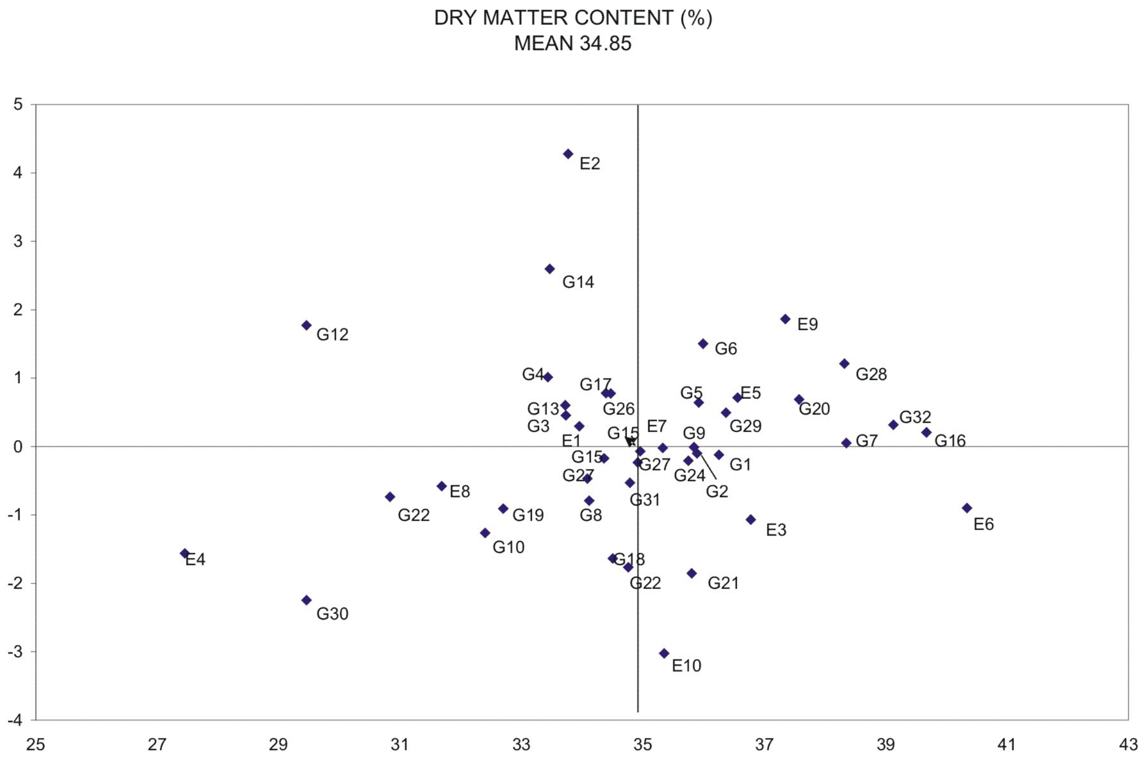
Table 12: AMMI analysis for the dry matter content (%) of 32 cassava genotypes evaluated in 10 environments in Nigeria.

Source	df	SS	MS	Probability
Total	639	20743.97805	32.46319	
TRT	319	17565.72478	55.06497	0.0000000 ***
GEN	31	3538.06784	114.13122	0.0000000 ***
ENV	9	7052.30000	783.58889	0.0000000 ***
G X E	279	6975.35695	25.00128	0.0000000 ***
IPCA 1	39	2625.62184	67.32364	0.0000000 ***
IPCA 2	37	1313.25394	35.49335	0.0000000 ***
IPCA 3	35	896.15445	25.60441	0.0000078 ***
IPCA 4	33	593.28038	17.97819	0.0053686 **
IPCA 5	31	565.68388	18.24787	0.0053405 **
IPCA 6	29	448.98567	15.48226	0.0364203 *
IPCA 7	27	338.90105	12.55189	0.1758767
Residual	48	193.47574	4.03074	0.9998565
Error	320	3178.25327	9.93204	

n = 640 Grand mean 34.857 %

*, **, ***, ns Significant at p<0.05, p<0.01, p<0.001 and Not Significant at p<0.05

IPCAi = Interaction Principal Component AxiS i



GENOTYPE					
G1 = 30572	G2 = 4(2)1425	G3 = 82/00058	G4 = 91/02324	G5 = 92/0057	G6 = 92/0067
G7 = 92/0325	G8 = 92/0326	G9 = 92B/00061	G10 = 94/0026	G11 = 94/0039	G12 = 94/0561
G13 = 95/0166	G14 = 95/0289	G15 = 96/0603	G16 = 96/1632	G17 = 96/1642	G18 = 97/0162
G19 = 97/0211	G20 = 97/2205	G21 = 97/4763	G22 = 97/4779	G23 = 98/0002	G24 = 98/0505
G25 = 98/0581	G26 = 98/2101	G27 = 98/2226	G28 = 99/2123	G29 = 99/3073	G30 = 99/6012
G31 = M98/0040	G32 = M98/0068				

ENVIROMENT				
E1 = Abuja	E2 = Calabar	E3 = Egbema	E4 = Ibadan	E5 = Ikenne
E6 = Ilorin	E7 = Kaduna	E8 = Mokwa	E9 = Ubiaja	E10 = Warri

Figure 3. AMMI biplot for dry matter content (%) of 32 cassava genotypes evaluated in 10 environments in Nigeria.

Table 13: Summary of stable genotypes based on AMMI analysis and 16 suggested varieties for 2003/2004 release.

	FYLD			DMC			DYLD				
Varieties in AMMI analysis	Stable and above average (between 1 and –1 IPCA1 value)	Stable and below average (between 1 and –1 IPCA1 value)	Unstable (>1 and <–1 IPCA1 value)	Stable and above average (between 1 and –1 IPCA1 value)	Stable and below average (between 1 and –1 IPCA1 value)	Unstable (>1 and <–1 IPCA1 value)	Stable and above average (between 1 and –1 IPCA1 value)	Stable and below average (between 1 and –1 IPCA1 value)	Unstable (>1 and <–1 IPCA1 value)	Suggested varieties for release	Reason
G1 = 30572	.	1	.	1	.	.	.	1	.	.	.
G2 = 4(2)1425	.	1	.	1	.	.	1	.	.	.	.
G3 = 82/00058	.	.	.	.	1	.	1	.	.	.	.
G4 = 91/02324	1	.	.	.	1	.	.	.	1+	1	High stable FYLD, DMC, and unstable but high DYLD
G5 = 92/0057	.	1	.	1	.	.	1	.	.	1	High stable FYLD, DMC, and DYLD
G6 = 92/0067	1	.	.	.	.	.	1	.	.	.	.
G7 = 92/0325	.	1	.	1	.	.	.	1	.	.	.
G8 = 92/0326	.	1	.	.	1	.	1	.	.	1	High stable FYLD, DYLD, and low stable DMC
G9 = 92B/00061	1	.	.	1	.	.	1	.	.	1	High stable FYLD, DMC, and DYLD
G10 = 94/0026	1	.	.	.	.	.	1	.	.	.	.
G11 = 94/0039	1	.	.	.	.	.	1	.	.	.	.
G12 = 94/0561	.	.	.	.	.	.	.	1	.	.	.
G13 = 95/0166	.	.	.	.	1	.	.	.	.	.	.
G14 = 95/0289	1	.	.	.	.	1–	1	.	.	1	High stable FYLD, DYLD, and unstable but low DMC
G15 = 96/0603	.	.	.	.	1	.	1	.	.	.	.
G16 = 96/1632	.	.	1+	1	.	.	1	.	.	1	High stable DMC, DYLD, and unstable but high FYLD
G17 = 96/1642	1	.	.	.	1	.	1	.	.	.	§
G18 = 97/0162	1	.	.	.	.	.	1	.	.	.	.
G19 = 97/0211	.	1	.	.	1	.	.	1	.	.	.
G20 = 97/2205	.	.	1+	1	.	.	1	.	.	1	High stable DMC, DYLD, and unstable but high FYLD
G21 = 97/4763	1	.	.	.	.	1+	1	.	.	1	High stable FYLD, DYLD, and unstable but high DMC
G22 = 97/4779	.	.	.	.	1	.	.	.	.	.	.
G23 = 98/0002	.	.	.	.	.	.	1	.	.	.	.
G24 = 98/0505	1	.	.	1	.	.	1	.	.	1	High stable FYLD, DYLD, DMC
G25 = 98/0581	1	.	.	1	.	.	1	.	.	1	High stable FYLD, DYLD, DMC
G26 = 98/2101	1	.	.	.	1	.	1	.	.	.	§
G27 = 98/2226	.	1	.	.	1	.	.	1	.	.	§
G28 = 99/2123	.	1	.	.	.	.	1	.	.	.	.
G29 = 99/3073	1	.	.	1	.	.	1	.	.	1	High stable FYLD, DYLD, DMC
G30 = 99/6012	.	1	.	.	.	.	.	1	.	.	.
G31 = M98/0040	.	1	.	.	1	.	.	.	.	.	.
G32 = M98/0068	.	.	1+	1	.	.	1	.	.	1	High stable DYLD, DMC, and unstable but high FYLD
										TME 419	Highest *gari* percent
										92B/00068	High starch and *gari* percent
										97/3200	CMD resistant, high starch and *gari* percent
										98/0510	High shape and size index, starch and *gari* percent

Varieties in bold italics are checks; +: above average performer; –: below average performer; §: could have made the suggested list but did not meet cutoff for DMC;

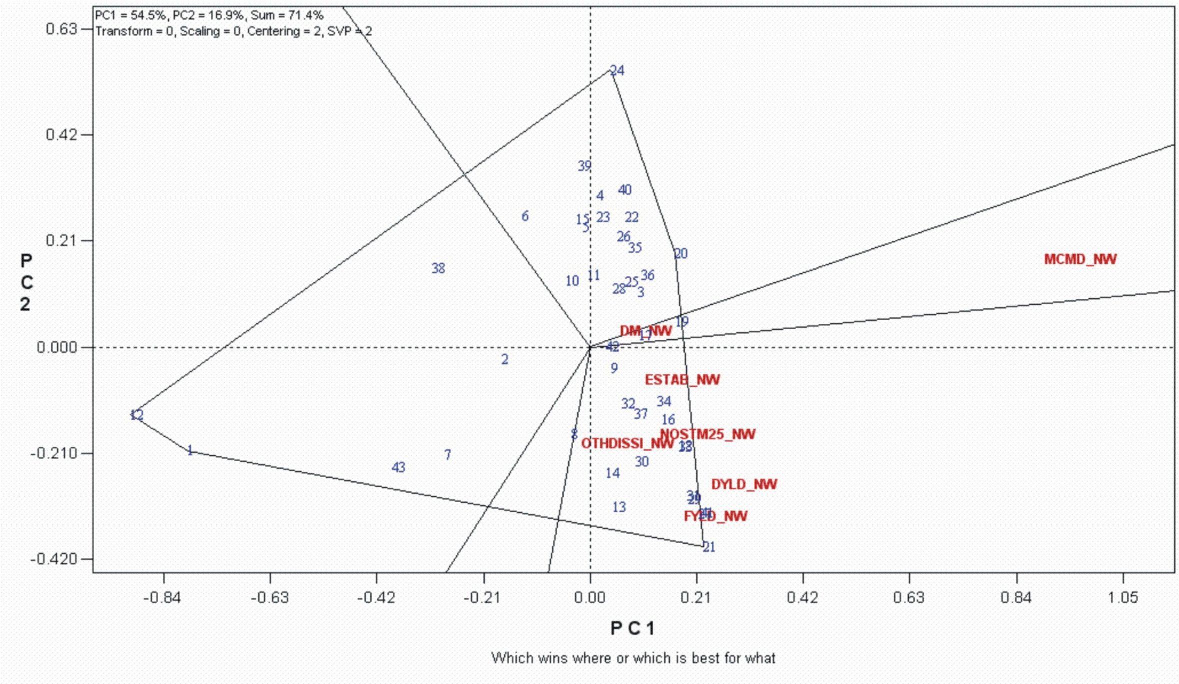


Figure 4. Biplot of 43 genotypes and 7 traits using GGE Biplot.

Code	Clone
1	4(2)1425
2	82/00058
3	91/02324
4	92/0057
5	92/0067
6	92/0325
7	92/0326
8	92B/00061
9	92B/00068
10	94/0026
11	94/0039
12	94/0561
13	95/0166
14	95/0289
15	95/0379
16	96/0523
17	96/0603
18	96/1089A
19	96/1565
20	96/1569
21	96/1632
22	96/1642
23	97/0162
24	97/0211
25	97/2205
26	97/3200
27	97/4763
28	97/4769
29	97/4779
30	98/0002
31	98/0505
32	98/0510
33	98/0581
34	98/2101
35	98/2226
36	99/2123
37	99/3073
38	99/6012
39	M98/0028
40	M98/0040
41	M98/0068
42	TME419
43	TMS30572

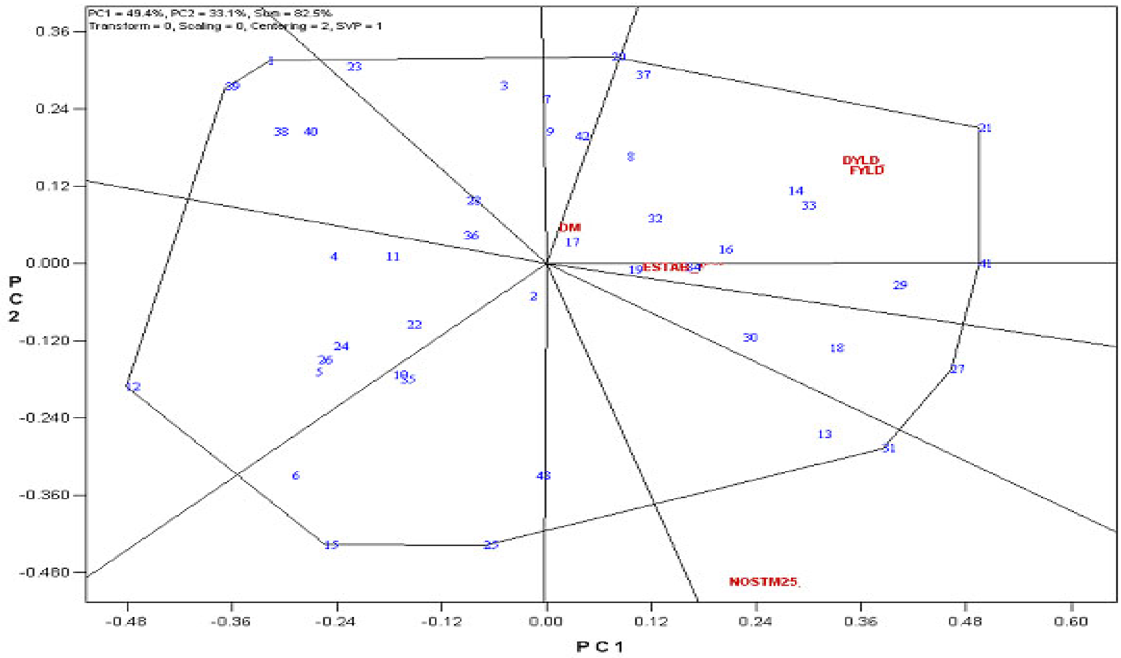
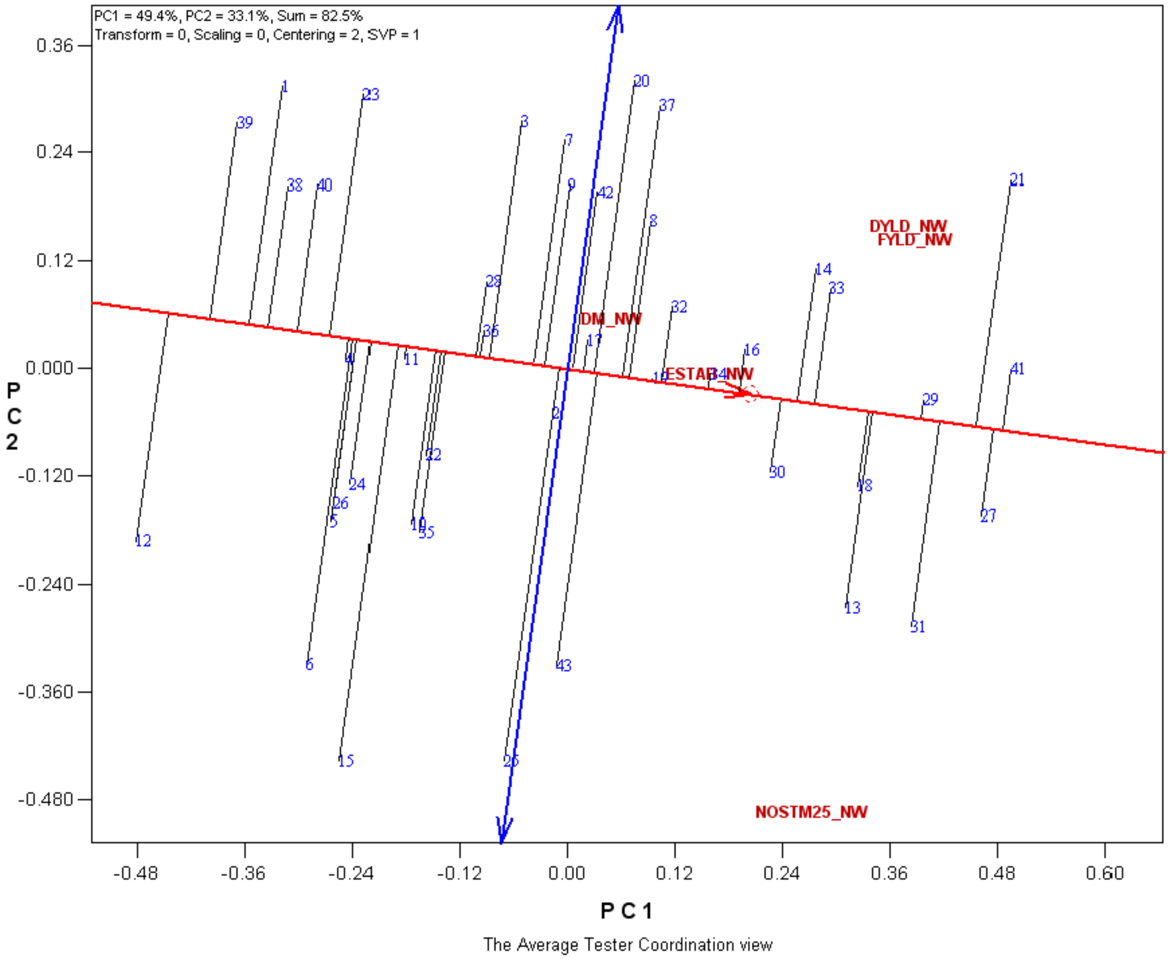


Figure 5. GGE biplot showing relative proximity of clones to FYLD and DYLD in 2004/2005 evaluation.



1=4(2)1425,	2=82/00058,	3=91/02324,	4=92/0057,	5=92/0067,	6=92/0325,
7=92/0326,	8=92B/00061,	9=92B/00068,	10=94/0026,	11=94/0039,	12=94/0561,
13=95/0166,	14=95/0289,	15=95/0379,	16=96/0523,	17=96/0603,	18=96/1089A,
19=96/1565,	20=96/1569,	21=96/1632,	22=96/1642,	23=97/0162,	24=97/0211,
25=97/2205,	26=97/3200,	27=97/4763,	28=97/4769,	29=97/4779,	30=98/0002,
31=98/0505,	32=98/0510,	33=98/0581,	34=98/2101,	35=98/2226,	36=99/2123,
37=99/3073,	38=99/6012,	39=M98/0028,	40=M98/0040,	41=M98/0068,	42=TME419,
43=TMS30572					

Figure 6. Stability biplot of 43 genotypes and 5 traits using GGE biplot.

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Distribution of yam anthracnose disease in Nigeria

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Abstract

Yam anthracnose disease, characterized by leaf necrosis and shoot die-back, is a major constraint to the cultivation of yam, especially water yam (*Dioscorea alata* Linn.) . Studies were conducted on the distribution of the disease in the major yam growing zones in Nigeria. Yam anthracnose disease was found to be widely distributed in 148 farmers' fields in three agroecologies. The incidence was 52.2% in the southern Guinea savanna, 51.3% in the forest/savanna transition, and 40.3% in the humid forest, with *D. alata* having the highest severity score followed by *D. rotundata. Colletotrichum gloeosporioides* (Penz) was the pathogen most commonly associated with the symptoms of anthracnose based on isolations from leaf samples collected from the farmers' fields. *Fusarium* spp., *Rhizotonia solani* (Kuhn), *Botryodiplodia theobromae* (Pat), and *Macrophomina phaseolina* (Tassi) were also isolated from the infected yam leaves.

Keywords: Yam, *Dioscorea* species, anthracnose, yam diseases

Introduction

Yam (*Dioscorea* spp.) are an important food crop in many tropical areas of the developing world, in particular the yam growing zones of West Africa (Farhat et al 1999). Anthracnose disease is a major constraint to the production of *D. alata* (Abang et al 2002). The disease is caused by the pathogen *Colletotrichum gloeosporioides* Penz. (Wharton 1994, Abang 1997), which has been reported to infect a wide range of host species throughout the world (Bailey and Jeger 1992; Sutton 1992). It also survives as a saprophyte on senescent plant material. *Colletotrichum gloesporioides* is a large species aggregate that has been isolated from several host plants (Lourd et al 1979), such as avocado (*Persea americana* Mill.), banana (*Musa* spp.), cacao (*Theobroma cacao* L.), coffee (*Coffea arabica* L.), mango (*Mangifera indica* L.), pawpaw (*Carica papaya* L.), rubber (*Hevea brasiliensis* Willd.), and a variety of other tropical plants (Jeffries et al 1990). Diseases caused by *C. gloeosporioides* have been reported in a variety of forms, including anthracnose of stems and leaves, die-back, root rot, leaf spot, blossom rot, fruit rot, and seedling blight.

Foliar anthracnose of yam caused by *C. gloeosporioides* is widespread in the tropics. It causes considerable crop losses in the Caribbean (Degras et al 1984), India (Singh and Prasad 1967), the South Pacific (Van Wijimeersch 1987), and West Africa (Nwankiti and Ene 1984; Abang et al 2002). In the Caribbean, for example, yield losses of over 90% have been reported (Degras et al 1984). Akem and Asiedu 1994 reported its attack on all widely cultivated species of *Dioscorea* in Nigeria and some varieties of *D. alata* are particularly susceptible to the disease. The objective of this study was to determine the distribution of anthracnose disease in different agroecological zones (AEZ) of Nigeria as influenced by the dominant yam species grown.

Materials and Methods

A survey was conducted in major yam growing zones of Nigeria between September and October 1999. The survey covered 14 States across three AEZ (humid forest, forest/savanna transition, and Guinea savanna) in 14 States, Oyo, Kwara, Niger, Kaduna, Nasarawa, Benue, Taraba, Cross River, Abia, Enugu, Ebonyi, Akwa Ibom, Rivers, and Imo. The States and villages were selected based on the previous work of Green (1995) on the distribution and severity of foliar diseases of yam. Within each State, fields were sampled at about 20 km from each other. A global positioning system receiver (Magellan GPS NAV DLX-10™, Magellan System Corporation, 960

Overland Court, San Dimas, California 91773, USA) was used to record the geographical coordinates of each of 148 yam fields visited. Fields were first scored for the presence or absence of anthracnose. Where the disease was present, the severity of the attack was determined. The results of Winch et al (1984) and Akem and Asiedu (1994) in an earlier study confirmed typical anthracnose symptoms to be leaf spots, superficial blackening, underside lesions, and blight. For the determination of disease severity (DS), at least 10 adjacent plants selected at random were observed in each field. Plants were then rated visually on a scale ranging from 1 to 5 as follows:

Healthy looking plant or with a trace of disease –1
Symptoms of anthracnose – 2 in 2-10 % of leaf area
Symptoms of anthracnose – 3 in 11-25% of leaf area
Symptoms of anthracnose – 4 in 26-50% of leaf area
Symptoms of anthracnose - 5 in >50% of leaf area
Percentage disease incidence was calculated using the following formula:

$$PI = n/N \times 100/1$$

Where PI= Percentage incidence; n = number of plants showing anthracnose symptoms; N = total number of plants.

Samples of infected leaves were also collected for isolation of the causal organism. On each yam field surveyed, agronomic practices such as staking, mounding, and mulching were recorded to assess their possible relationship with disease severity and distribution in the fields.

Results and Discussion

Yam production systems. A map of Nigeria is presented showing locations where anthracnose-diseased yam leaves (isolates of *C. gloeosporioides*) were collected (Fig. 1). Yam cultivation on the farms differed with respect to practices for intercropping, staking, and land preparation. Intercropping of yam with other crops, such as maize, cassava, vegetables, and cocoyam was more common in the forest/savanna transition than in the two other AEZ.

Staking was commonly practiced and in most fields dead wood was used or live trees/shrubs for this purpose (Table 1). Yam were not staked in 22% of the fields in the humid forest and 30% in the Guinea savanna. The methods of land preparation employed were mounding and ridging, but mounds were more commonly used across the AEZ: 86% in the Guinea savanna, 68% in the humid forest, and 84% in the forest/savanna transition zone. Ridging was used in 13% of the farms in the Guinea savanna, 32% in the humid forest, and 13% in the forest/savanna transition zone. Across the yam growing zones, *D. rotundata* was the most widely cultivated yam species with an occurrence of 48%, followed by *D. alata* with 32% (Table 2).

Incidence and severity of anthracnose disease in three agroecologies. Anthracnose disease was observed in 98% of the 148 fields sampled. Disease incidence was higher in the southern Guinea savanna and the forest/savanna transition than in the humid forest (Table 3). Severity varied from a few leaf spots to complete necrosis of all yam stands in the field and was highest in the humid forest, followed by the southern Guinea savanna and forest/savanna transition (Table 4). Mean scores of ≥ 3 were recorded for *D. alata* across the three AEZ while *D. rotundata* and *D. cayenensis* had severity scores of < 3. Severity of anthracnose on *D. dumetorum* was highest (3.29) in the forest/savanna transition zone. *Dioscorea esculenta* and *D. bulbifera* had low (≤ 2) severity scores but these species were present in only two AEZ. A wide diversity of yam cultivation methods were observed in practices for staking and land preparation. Staking of yam vines, according to Nwankiti and Ahiara (1984), Nwankiti and Ene (1984) and Akem and Asiedu (1994), reduces the incidence and severity of anthracnose while intercropping tends to increase its severity. Yam anthracnose disease was most severe in the humid forest, indicating a positive relationship between disease severity and rainfall. This agrees with the findings of Sweetmore et al (1994) and Akem and Asiedu (1994) that rainfall, warm temperatures, and high relative humidity are important factors in the severity of anthracnose disease. *Dioscorea alata* was seriously affected followed by *D. rotundata* in all the AEZ surveyed. The implication of this result is that anthracnose disease is a serious threat to the production of yam in Nigeria and resistant varieties should be used in the expansion of *D. alata* cultivation to take advantage of its superiority in ease of propagation, high yielding potential and vigor.

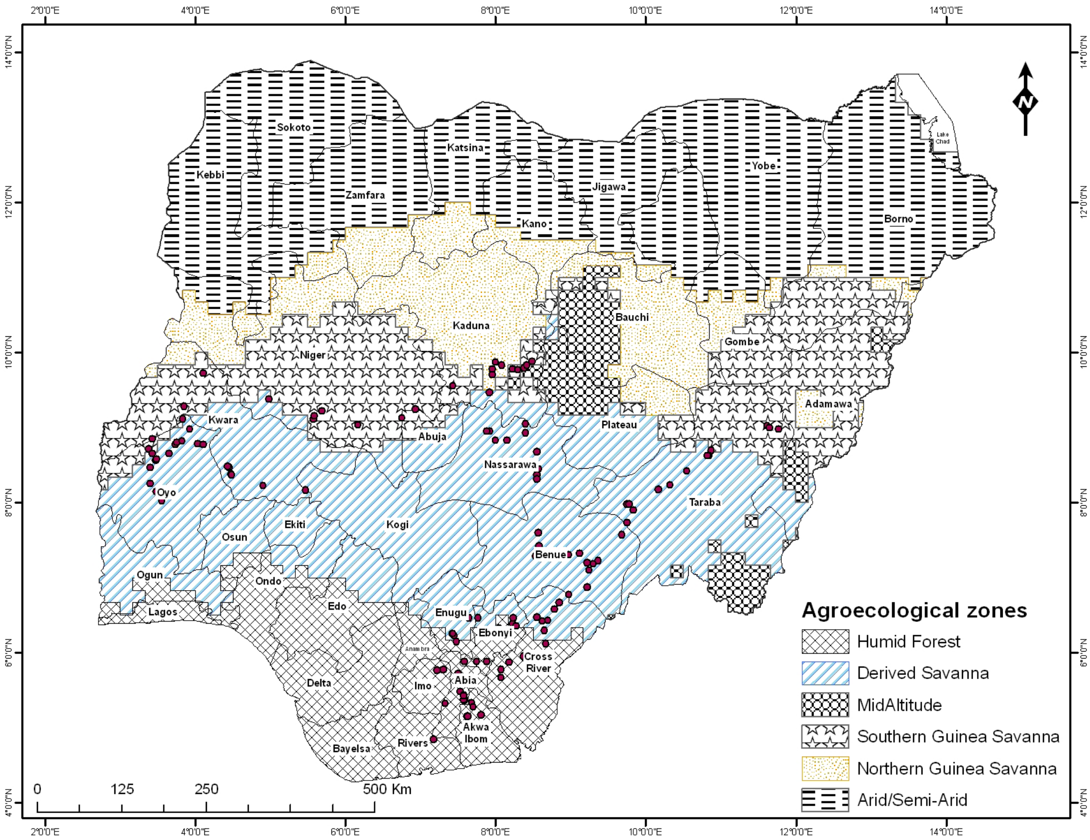

Figure 1. Nigeria, showing locations (●) where anthracnose-diseased yam leaves (isolates of *C. gloeosporioides*) were collected.

Table 1: Cultural practices identified on yam farms in a survey conducted in Nigeria in 1999.

AEZ	Disease severity(1–5)	Land preparation (%)			Material used for staking (%)			
		Ridge/ mound*	Mound	Ridge	Nil	Dead wood	Live tree/ shrub	Cereal stalk
Forest/savanna transition	2.02	3.3	84	13	3.3	11	86	2
Guinea savanna	2.76	0.0	86	13	30	51	19	0
Humid forest	2.95	0.0	68	32	22	75	3	0

*Mixture of ridges and mounds on the same farm

Table 2: *Dioscorea* spp. found in yam fields sampled during a survey in Nigeria in 1999.

Dioscorea sp	No. of fields			Total
	HF	FS	GS	
D. rotundata	48	26	62	136 (48.4)
D. alata	45	19	27	91(32.4)
D. cayenensis	9	-	7	16 (5.7)
D. dumetorum	13	7	9	29 (10.3)
D. bulbifera	3	-	3	6 (2.1)
D. esculenta	1	1	1	3 (1.1)

HF- humid forest
FS – forest/savanna transition
GS –Guinea savanna

Table 3: Incidence and severity of anthracnose disease in three AEZ of Nigeria.

AEZ	Incidence	Severity
Transition savanna	51.33	2.02
Guinea savanna	52.20	2.76
Humid forest	40.30	2.95

Table 4: Mean severity of anthracnose disease on *Dioscorea* spp. in three AEZ of Nigeria.

AEZ	*D. rotundata*	*D. alata*	*D. cayenensis*	*D. dumetorum*	*D .bulbifera*
Forest/transition	3.00 ± 0.52 (n=16)*	3.10 ± 0.88 (n=15)	2.86 ± 0.69 (n=7)	3.0 ± 0.76 (n=7)	-
Guinea savanna	2.69 ± 0.68 (n=72)	2.94 ± 0.98 (n=31)	-	2.33 ± 0.68 (n=9)	1.83
Humid forest	2.87 ± 0.97(n=52)	3.50 ± 1.10 (n=43)	2.70 ± 0.71 (n=9)	3.00 ± 0.91 (n=!3)	-

*Severity based on scoring categories where 1=1%, 2=2-10%, 3=11-25%, 4=26-50%, 5>50% of leaves infected.

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Empirical estimation of demand function and elasticities for seed yam in southern Nigeria

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Abstract

This study was conducted to assess the influence of economic variables on the value of seed yam demanded in Southern Nigeria using demand function analyses. A cross sectional data was collected from 150 seed yam farmers spread across three major yam producing States in 2006 using the multi-stage random sampling technique. Results show that education and income were negatively related to value of seed yam demanded in Ebonyi State. Price of seed yam had a negative relationship and significant at 5.0% level while farm size and fertilizer were directly related to value of seed yam demanded at 1.0% level. In Delta State, education and farmer experience were negatively related to seed yam demand and these were significant at 1.0%. Variable inputs were negatively related and significant at 5.0% level while income and farm size were directly related to the value of seed yam demanded and significant at 1.0% and 10.0% levels. In Cross River State, age, education, labour, and farm size had a direct relationship with seed yam demand at 1.0% level. Fertilizer and variable inputs were negatively related to seed yam demand at 5.0% level of probability. The elasticity of demand for seed yam to farm size was positive for Ebonyi State but inelastic for Cross River and Delta. The elasticities of demand for education in Cross River (0.78), Delta (1.20), and Ebonyi(-0.41). The elasticity for labour in Cross River State was 0.13. Own-price elasticities were -0.170 (Delta), -0.440 (Ebonyi), and 0.054 (Cross River). The cross price elasticities for seed yam with respect to the price of major substitutes in the three States were all positive. The income elasticities of demand for seed yam are positive for Delta and Cross River but negative for Ebonyi. There is a need therefore for policies aimed at encouraging farmers to increase cultivation of seed yams, and improving farmers' access to fertilizer and other inputs. Farmers should be exposed through extension services to the benefit of seed yam enterprise for increased commercialization.

Keywords: Seed yam, *Dioscorea* species, yam demand function, Agroenterprise

Introduction

Yam is an important crop in the West African sub-region and is Nigeria's foremost root crop. Unlike other staples, millet, maize, and sorghum, yam is generally accepted by all ethnic groups in Nigeria (FAO 2002). It contributes about 300 dietary calories per day in the diet of Nigerians. The importance of yam in Nigeria depends on its high level of calories and protein. Nigeria is the largest world producer of yam with annual production estimated at 26.587 million (FAO 2006). The crop contributes significantly to national economies and rural income by providing employment to many rural dwellers. Yam production has however not kept pace with population growth leading to demand exceeding supply (Kushwaha and Polycarp 2001). Annual demand for yam in Nigeria is estimated at 30 million metric tonnes, and this gap is still increasing with annual increase in population (Ikeorgu and Asiedu 2006). There is also the need for yam to satisfy domestic and export demand. Seed yam account for over 40% of the cost of yam production (Ugwu 1990, Nweke et al 1991). The edible part of the yam is also used as planting material. This has put pressure on its availability as planting material (Oyolu. 1978). This prompted the development of the yam minisett technique by the National Root Crops Research Institute, Umudike in the early 1980s (Okoli et al 1982).

The minisett technique of seed yam production holds a lot of prospects for reducing the cost of seed yam. It is necessary to understand the demand structure for seed yam to help producers and other entrepreneurs in the sub-sector business.

The basic model of demand states that the amount demanded of any good depends on the good's own price, consumers' income, the prices of substitutes and complements, consumers' preferences and perhaps other factors. Some researchers have expressed the need to consider a wider range of explanatory variables than the price and consumer income variables suggested by economic theory (Effiong and Njoku, 2001). The objective of this study is, therefore, to analyze the demand for seed yam in major yam producing areas of Southern Nigeria. The specific objectives are to:

i. identify and describe the characteristics of the various participants in the seed yam sub-sector in this region;
ii. estimate and analyze the demand for seed yam in these major producing areas;
iii. examine the relative demand elasticities for the yam; and
iv. make policy recommendations

Methodology

The study was carried out in the major yam producing Southern States of Nigeria, Ebonyi, Delta, and Cross River.

Sampling procedure for data collection. The study adopted the multi-stage random sampling procedure in the choice of States selected for the study. In the second stage, an agricultural zone was chosen from three of the Agricultural Development Project zones in each of the selected States. In the third stage, 50 seed yam producers were randomly selected, making a total of 150 yam producers from the zones selected.

Data were collected using structured questionnaires on the socio-economics of the farmers, employment, household expenditure on seed yam, inputs, complements and substitutes, quantity and value of seed yam demanded, price of seed yam and close substitute. Others were disposable income, household size, and experience in seed yam production. Also collected were information on age and education of the household heads; their major and minor occupations; gender of the household head; farm sizes; labour use; inputs, and access to credit in 2006.

Conventional demand function analysis via a cross-sectional model was employed to assess the influence of these economic variables on the value of seed yam demanded. Descriptive statistics as well as linear regression models were applied to estimate the effect of the above variables on seed yam demand. Partial derivatives of the various elasticity formulae were estimated (Adepoju 2006)

The demand function for seed yams is implicitly specified in equations 1–3:

$$Y = f\,(age, edn, i, L, Fs, Exp, Ps, P, Fertkg, Vi, e \quad (1)$$

$$Y = y_P + y_B, \quad (2)$$

$$i = G_i - G_0 \quad (3)$$

Where:

Y	=	value of seed yam demanded (in Naira)
y_P	=	value of own produced seed yam (in Naira)
y_B	=	expenditure on seed yam purchase by growers (in Naira)
age	=	age of household head (in years)
edn	=	level of education of household head (in years)
i	=	disposable income of household head (in Naira)
G_i	=	gross income of household (in Naira)
G_0	=	income given away (in Naira)
L	=	labour input in mandays
Fs	=	farm size (hectares)
Exp	=	years of farming experience
Ps	=	price per kg of close substitutes (in Naira)
P	=	price of seed yams per kg (in Naira)
Fertkg	=	quantity of fertilizer used (kg)
Vi	=	other variable inputs (amount spent on pesticides and herbicides) (in Naira).
e	=	error term

Demand elasticity for seed yam.

Demand elasticity is defined as the responsiveness of demand to changes in price. For linear functions, price elasticity of demand can be written thus,

$$E_d = \underline{d_{q/}}\, d_P \times \underline{p/q}$$

$$= b.\ P_i/q_i$$

Where;

E_d	=	elasticity of demand
d_q	=	change in quantity demanded
d_P	=	change in price
P_i	=	mean value of the explanatory variables
q_i	=	mean value of the dependent variable
b_i	=	coefficient of the variables

Own price, cross price, and income elasticities were also determined.

Results and Discussion

Average Statistics of Seed Yam Farmers The average statistics of the sampled seed yam farmers are presented in Table 1. Seed yam growers in Ebonyi and Cross River were middle-aged. This is the active

Table 1: Average Statistics of Seed Yam Farmers in Southern Nigeria.

Variables	Ebonyi	Cross River	Delta
Demand (N)	40,704.72	22,944.00	54,375.00
Age (yrs)	49.20	44.14	58.06
Education (yrs)	5.56	8.10	6.04
Major occupation	0.90	0.74	0.92
Income (₦)	250,960.00	175,170.41	245,451.22
Labour (mandays)	158.44	1100.21	371.66
Farm Size (ha)	3.86	2.22	2.01
Experience (yrs)	30.61	20.38	26.28
Price of major substitutes (₦)	200.95	232.20	263.22
Price of seed yam (₦)	23.96	17.45	27.71
Fixed input (₦)	3942.40	7822.47	5050.60
Fertilizer (kg)	473.26	172.22	87.22
Other variable inputs (₦)	6.94	8.25	129.46

Source: Derived from field data, 2006.

Table 2. Demand Functions for Seed Yam Northern Nigeria

Variable	Ebonyi	Delta	Cross river
Constant	78444.394**	(2.227)	190857***
	(3.721)	-52337.05***	(-3.347)
Age of House Hold Head (age)	-455.373	(-0.755)	-104.675
	(-0.630	1296.972***	(3.449)
Educational Level (edn)	-2988.160***	(-3.407)	-10689.43***
	(-3.884)	2218.958***	(3.468)
Disposable Income (I)	-4.341E-02***	(-5.068)	0252***
	(4.003)	7.365E-02**	(2.212)
Labour Availability (L)	-85.002	(-2.267)	12.367
	(0.571)	2.760***	(4.317)
Farm Size (Fs)	10633.429***	(5.647)	11286.506*
	(1.912)	8280.294***	(4.125)
Experience (Exp)	756.938	(1.067)	-2759.257***
	(-3.804)	-390.378	(-1.007)
Price of Substitute (Ps)	13.221	(0.273)	17.340
	(0.374)	7.572	(0.542)
Price of Seed Yam (P)	-754.437**	(-2.664)	-332.573
	(-0.509)	71.517	(0.334)
Fertilizer in kg (Fertkg)	1.070***	(2.959)	-1.199
	(-0.779)	-53.255**	(-2.489)
Variable Imputs (Vi)	-4018.494	(-1.019)	-8823.990**
	(-2.240)	-2380.780**	(-2674)
R^2	0.760	0.738	0.844
Adjusted R^2	0.644	0.629	0.725
F-values	7.929***	6.775***	7.053***

Source: Derived from survey data, 2006.
Note: *, ** and *** = Significant at 10%, 5% and 1% respectively
Values in parenthesis are the t-values.

farming group. However, in Delta, the mean age of farmers was 58 years; the farming household heads are aging and may not be very active for long. The mean number of years of schooling of the seed yam growers was about 6 years in Ebonyi and Delta and 8 years in Cross River which implies primary school leavers. Most of them grow seed yam as their major occupation with a mean farm size of between 2 and 4 ha. The annual average disposable income is between ₦245, 000 and ₦250, 000 for farmers in Delta and Ebonyi and below ₦200, 000 for farmers in Cross River.

Demand for seed yam. The result of the parameter estimates in the linear regression analysis is shown in Table 2. The value of seed yam demanded in (₦) was the dependent variable (Y), and the independent variables were as shown in the Table. The regression model explained 63-73% of the total variation in the States studied. The F-ratio shows that the regression was statistically significant at the 1.0 per cent level of probability.

The coefficient for own price of seed yam (P) was negative and significant in Ebonyi State. This result in Ebonyi State conforms to a priori expectation as price increases are expected to lead to reduction in quantities demanded of normal goods. Thus, farmers will demand for additional seed yams only when the price is low otherwise they make do with reserves from last years' harvest. The results of the analyses also suggest that age exerts a positive and significant effect on seed yam demand by household heads in Cross River. Thus, the elderly are more in seed yam demand in this State.

Farm size was significant and positive for all the States which implies that higher farm sizes urge farmers to demand more seed yam.

Availability of fertilizer encourages the demand for more seed yam by farmers in Ebonyi. Findings have indicated a positive relationship in this regard and it is manifest in this result. Ebonyi has a fertilizer blending plant unlike other States in the south-east. The plant is adequately supplied with raw materials such as lime within the State. It has the capacity to produce 40 t of NPK fertilizer per hour. Apart from this fertilizer blending plant, there are other dealers around the State who procure fertilizer from Lagos for sale to farmers. Fertilizer in the State is distributed through wholesalers, retailers, Local Government Areas, and farmers' associations. The Agricultural Development Project plays a key role in getting fertilizer to the farmers.

Education was positive and significant for Cross River, indicating that increases in educational level bring about increases in seed yam demand in these States. For Ebonyi and Delta, education was found to be a significant determinant of demand for seed yam but had a negative and significant effect at the 1.0% level. This implies that education exposes farmers in these two States to other sources of income, employment,

Table 3. Estimated Elasticities of Economic Variables on Demand for Seed Yam

Variables	Cross River	Delta	Ebonyi
Age	2.49	-0.11	-0.60
Education	0.78	1.20	-0.41
Labour	0.13	0.10	-0.33
Farm Size	0.80	0.42	1.01
Experience	-0.35	-1.30	0.60
Fertilizer(kg)	-0.39	-0.00	0.01
Variable Inputs (VI)	-0.86	-21.01	-0.70
Total	3.22	-20.74	-0.89

Source: Derived from survey data, 2006

Table 4. Own Price, Gross Price and Income Elasticities of Seed yam Demand.

Elasticity	Cross-River	Delta	Ebonyi
Own price	0.054	-0.17	-0.44
Gross price	0.077	1.83	1.60
Income	0.562	0.13	-0.03

Source: Derived from survey data, 2006.

and livelihood. It is worth mentioning that unlike the above two States, Ebonyi is one of the educationally disadvantaged areas in Nigeria.

Disposable income was found to be a significant determinant of the quantity of seed yam demanded in all the States. The relationship is, however, negative for Ebonyi, indicating that increases in income will bring about decreases in the quantity demanded.

Availability of labour in man-days was found to be a positive and significant determinant of seed yam demand at 1.0% level of probability for Cross River. This implies that an increase in labour availability brings about an increase in seed yam demand in this State.

The elasticity of demand for seed yam with respect to farm size was positive for Ebonyi but inelastic for Cross River and Delta (Table 3.). This implies that increases in farm sizes will bring about a more than proportionate increase in seed yam demand in Ebonyi and a less than proportionate increase for Cross River and Delta.

The elasticity with respect to education for Cross River was 0.78. This implies that increases in the educational level of respondents will bring about a less than proportionate increase in the quantity of seed yam demanded. For Delta, the elasticity was 1.20, indicating that increases in education lead to a more than proportionate increase in seed yam demand. The elasticity of demand for seed yam in Ebonyi with respect to education was found to be -0.41.

This indicates an inelastic situation, implying that increases in the level of education will in the long run bring about a less than proportionate decrease in the demand for seed yam.

The elasticity for labour in Cross River was 0.13, implying that demand is still inelastic for the State. This implies that increases in labour availability will bring about a less than proportionate increase in seed yam demand.

Price elasticities. Table 4 presents the respective computed own price, cross price, and income elasticities of demand for seed yam. In accordance with utility theory, the own price elasticities are negative for Ebonyi and Delta. Demand is price inelastic for these States with respect to their own price. Own price elasticities ranged from -0.170 for Delta to -0.440 for Ebonyi. The positive own price elasticities of demand for seed yam in Cross River may be accounted for either by the fact that there is not much variability in the price of seed yam in this State.

The cross price elasticities for seed yam with respect to the price of major substitutes in all the States are all positive, indicating that the products are substitutes.

The income elasticities of demand for seed yam are positive except for Ebonyi, suggesting that seed yam in these States are normal goods whose production will increase with increasing total disposable income on seed yam. For Delta and Cross River, the coefficient of income was positive and significant at 1 and 5.0% levels, implying that an increase in income in these States will bring about an increase in seed yam demand. The elasticities were found to be 0.13 for Delta and 0.56 for Cross River. This implies that a 1.0% increase in income will bring about a less than proportionate increase in the quantity of seed yam demanded.

Conclusion

The study has indicated that seed yam farmers in Southern Nigeria are predominantly middle aged, except in Delta, with a low level of literacy. Farmers sell seed yam only after satisfying their own requirements. Relevant economic variables influencing demand for seed yam in Southern Nigeria include age, farm size, education level, and the disposable income of the farmers. Others are experience in seed yam production and labour availability. These results call for policies aimed at encouraging farmers to increase cultivation of seed yam and improving farmers' access to fertilizer and other inputs. Thus, for the commercialization of the seed yam sector, farmers should be exposed to the benefits of seed yam enterprises through the extension services.

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Varietal response of seven new hybrid yam varieties to minituber production using the microsett Technique

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Abstract

A 2-year study at the National Root Crops Research Institute Umudike in 2005 and 2006 evaluated the performance of seven new hybrid yam varieties in minituber production using the recently developed microsett technique. One hundred 8g microsetts were cut from each of seven hybrid yam varieties as well as a local best (control). These were treated with a fungicide/insecticide mixture, cured overnight, and planted in randomly allocated plots in nursery chambers. The trial was laid out in RCBD design with three replicates. The microsetts were spaced 20cm x 10cm in the nursery to give a population of 500,000 plants/ha. Basal application of NPK at 200kg/ka was carried out at 12 WAP by the broadcast method and weeds were removed by hand pulling before fertilizer application. Five out of the seven hybrid yam were promising in terms of mean minituber yield/stand, minituber yield/ha, and sproutability at 4.6, and 8 WAP. The order of superiority was TDr 89/02461> TDr 89/02665> TDr 89/02677> TDr 89/01213> TDr 89/02565. These produced minituber sizes that ranged from 104g (TDr 89/02565) to 155g (TDr 89/02461); the mean size from the local best, Obioturugo, was 93g. TDr 89/02461 (6.7t/ha), TDr 89/02665 (5.9t/ha),TDr 89/02677 (5.7t/ha), and TDr 89/01213 (5.2t/ha) gave the significantly highest minituber yields/ha, the poorest yielder (1.3t/ha) was TDr 89/01438. These results have serious implications for seed yam production using the newly developed minituber technique.

Keywords: Yam, *Dioscorea* species, minituber production, seed yam, microsett technique

Introduction

Increased yam production depends largely on the availability of large quantities of healthy seed yam planting materials at the right time. It has been estimated that seed yam alone accounts for between 30 and 35% of the total cost of production (Nweke et al 1991, Ezeh 1991, Orkwor et al 1995). The high cost of seed yam has discouraged many farmers who have stopped planting yam and turned to cassava production as a cheaper alternative. The development of the yam minisett technique in the early 1980s (Okoli et al 1982) was seen as a major breakthrough to solve the constraint of scarcity and high cost of seed yam. However, over two decades after the development of the minisett technique, farmers' feedback showed that the rate of adoption was still below 40% (Ogbodu 1995, Anuebunwa et al 1998, Ikeorgu and Igbokwe 2002). High among the reasons for low adoption was that the size of the minisett (25 g) was too small to produce the desired size of seed yam. We addressed this low adoption rate in two ways, including the development of the minituber technique (Ikeorgu et al 2000, Ikeorgu and Nwokocha 2001, Ikeorgu and Igbokwe 2002).

The yam minituber technique was developed a decade ago as a technology complementary to the yam minisett technique for seed yam production (Ikeorgu and Nwokocha 2001). The use of minitubers instead of minisetts for seed yam production eliminates the need for cutting them into 25 g setts, treating cut surfaces with chemicals, curing overnight, etc. The farmer is simply given the desired number and size(s) of minitubers to plant directly into his farm. Trials conducted between 1998 and 2000 (Ikeorgu and Nwokocha, 2001) showed among other things that landraces and hybrid yam respond differently to minituber production. Some landraces even produce better minitubers than hybrid yam. As a result of the excellent collaborative research efforts of IITA, Ibadan, and the National Root Crops Research Institute (NRCRI), Umudike, in 2001 and 2003, the first ever seven hybrid yam were officially released in Nigeria by the NRCRI. But these are yet to reach most of the yam farmers in the Nigerian yam belt. The objective of this trial was to evaluate the performance of these newly released varieties in minituber production as a complementary method of rapid multiplication of these scarce planting materials.

Materials and Methods

This trial was conducted at NRCRI, Umudike, (5° 27'N; 7° 32'E and 122m above sea level) in 2005 and 2006. Five nursery chambers measuring 20 m × 2m wide and 50cm deep, constructed for this trial, were filled up to 10cm from the top with a mixture of topsoil and subsoil from the surrounding fallow lands. The sandy loam soil had 0.07% N, 31.8 me/kg P, 0.124 Cmol/kg K, and organic matter content of 1.41% at the beginning of this trial. From each of the improved hybrid yam varieties and a local best (Table 1), we cut 100 microsetts each weighing 8 g. Each seed yam was first weighed before cutting. Where a seed yam weighed about 80g, it was cut into 10 equal parts. The resulting microsetts were soaked for 5 min in a mixture of Mancozeb (100 g) and Basudin (70 ml) in 10l of water, and cured overnight before being planted out into the nursery chambers. The three middle chambers selected for this trial were each divided into 8 equal plots. The microsetts from hybrid yam and one local check were randomly allocated to the plots in a randomized complete block design, replicated three times.

Planting was done on 16 May in 2005 and on 23 May in 2006. The microsetts were planted at 20 cm × 10 cm in each plot to give a plant population of 500,000/ha. At 3 + 8 + 12 WAP, weeds were hand pulled so as to give minimum disturbance to the tender vines. NPK fertilizer at 200kg/ha was broadcast in each plot at 10 WAP.

Data were collected on sprouting at 4, 6 and 8 WAP. At harvest, each stand was weighed separately. These were used to compute the size range, mean tuber size/ variety and an estimate of the minituber yield /ha of 8g microsetts. Conventional analysis of variance for RCB design was carried out using SAS (2007) version 9.1 computer program and means were compared at 5% level of significance.

Results and Discussion

Sprouting. The percentage of sprouting from 8g microsetts of the hybrid yam varieties and a local best at 4,6 and 8 WAP are presented in Figure 1. At 4 WAP, only TDr 89/02565 and TDr 89/02677 had attained 30% sprouting or more. All the other varieties were above 25% except TDr 95/01924 and the local best cultivar, Obioturugo.

At 6 WAP, three varieties, TDr 89/02565: TDr 89/02665 and TDr 89/02677, had attained 70% sprouting and above while the others still had below 50% sprouting except the local best cultivar, Obioturugo. At 8 WAP, 8 g microsetts from five out of the hybrid yam varieties, as well as the local check, had attained 80% sprouting. There is a strong indication from this result that TDr 89/02565; TDr 89/2665; TDr 89/02677; TDr 89/02461, and TDr 89/01213 are most promising in terms of sprouting ability during the first 2 months of planting.

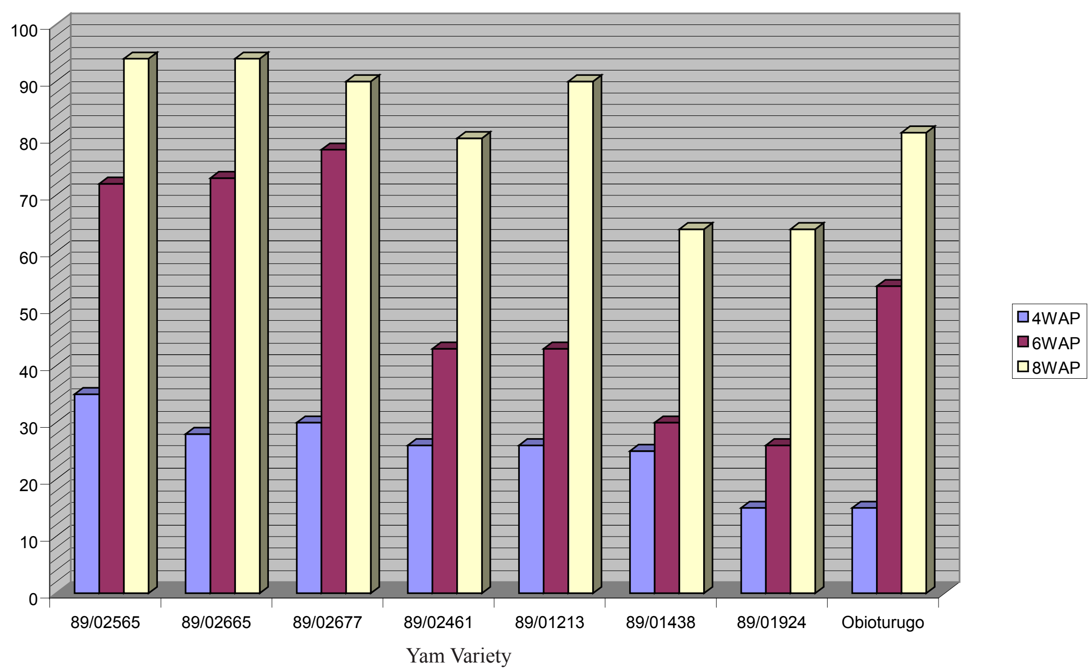

Figure 1. Percent sprouts from 8 g microsetts of 7 hybrid yam varieties in 2005 and 2006 (combined).

Minituber yield / stand. The mean minituber yield /stand from 8 g microsetts of the hybrid yams and a local best yam cultivar, is shown in Table 1. From the 2-year mean results, TDr 89/02461 (155 g) and TDr 89/02665 (140g) gave significantly highest minituber sizes. All the varieties evaluated produced minitubers larger than the 75 g recommended by Ikeorgu and Nwokocha (2001) as a suitable size for normal seed yam production. There is a strong indication therefore that 8g microsetts are larger that the size that could produce the desired minituber size of 75 g.

This confirms work by Ikeorgu and Nwokocha (2001) that 6 g microsetts are most suitable for producing the desired minituber sizes for economic seed yam production. The result also indicates that the TDr 89/02461 and TDr 89/02665 are most suitable for minituber production using the microsett technique.

Mean yield gain and multiplication ratio. The mean yield gain and multiplication ratio of minitubers from the hybrid yam varieties and a local check grown in 2005 and 2006 (combined) are presented in Table 2. These results agree with those in Table 2 above that TDr 89/02461 and TDr 89/02665 are significantly superior to the other yam varieties in terms of mean minituber size, mean yield gain and multiplication ratio. The other hybrid varieties did not perform better than the local best yam cultivar Obioturugo in terms of these attributes.

Mean minituber yield/ha. The mean minituber yields (t/ha) from 8 g micrsetts of the hybrid yam varieties and a local best cultivar, evaluated for suitability for minituber production in 2005 and 2006, are presented in Table 3.

The 2-year trial has shown that the hybrid yam vary significantly in both minituber yield performance and in minituber size and multiplication ratio. Although the 2-year results did not agree for TDr 89/02677 and TDr 89/02461 due, perhaps, to different soil types, the mean minituber yields show that TDr 89/02461; TDr 90/02665; TDr /02677; TDr 89/01213 are most promising and gave highest minituber yields/ha.

Conclusion

This 2-year study has identified some superior hybrid yam that are suitable for minituber production. These varieties are superior in terms of sproutability, size of minituber yield/stand, multiplication ratio and yield gain as well as minituber yield/ha. The order of superiority in performance was TDr 90/02461; TDr 89/02665; TDr 89/02677; TDr 89/01213, and TDr 89/02565. TDr 95/01924 was observed to take up to 10 weeks to sprout fully, resulting in lower total yield; TDr 89/01436 performed worst in all the attributes evaluated.

Table 1. Mean minituber yield/stand (g) for 7 hybrid yam varieties evaluated in 2005 and 2006

Hybrid yam varieties	Mean minituber yield/stand (g)		2 year mean
	2005	2006	
1. 89/02565	102.64b	106.62c	104.63b
2. 89/02665	109.16b	170.61a	139.89a
3. 89/02677	107.69b	108.96c	108.33b
4. 89/02461	171.10a	138.71b	154.91a
5. 89/01213	88.14b	89.06c	88.60b
6. 89/01438	74.62b	91.64c	83.13b
7. 95/01924	120.00b	87.74c	103.87b
8. Obioturugo	90.00b	97.82c	93.91b

Table 2. Mean yield gain and multiplication ratio of minitubers from seven hybrid yam varieties in 2005 and 2006 (combined)

Hybrid Yam Varieties	Yield gain / plant	Multiplication ratio
1. 89/02565	98.63b	17.4b
2. 89/02665	133.89b	23.3a
3. 89/02677	102.33b	17.1b
4. 89/02461	148.91a	25.8a
5. 89/0113	82.60a	14.8b
6. 89/01438	77.13b	12.9b
7. 95/01924	87.91b	15.65b
8. Obioturugo	87.91b	15.65b

Table 3. Mean minituber yields (t/ha) from 8 g micrsetts of seven hybrid yam varieties evaluated for suitability minituber production in 2005 and 2006.

Yam variety	Mean minituber yield (t/ha)		2-year
	2005	2006	means
1. 89/02565	4.15cd	5.65b	4.90b
2. 89/02665	6.25b	5.46b	5.86ab
3. 89/02667	8.59a	2.80cd	5.70ad
4. 89.02461	4.35c	8.97a	6.77a
5. 89/01213	5.33bc	5.00bc	5.17ab
6. 89/01438	1.08e	1.53d	1.31d
7. 89/01924	2.62de	4.07bc	3.35c
8. Obioturugo	3.23d	3.59c	3.41c

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Analysis of acceleration, deceleration and stagnation in output, land area, and yield of sweetpotato [*Ipomoea batatas* (L.) Lam] in Nigeria, 1961-2007

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Abstract

The study investigated the trends in the production, yield, and land area devoted to sweetpotato, the fourth-ranking root and tuber crop in Nigeria, at different periods between 1961 and 2007. It also estimated the compound growth rates and tested the hypotheses of the existence of acceleration or deceleration or stagnation in the growth of the variables. Secondary data collected from the FAO Statistical database were used for the study. Data were analyzed using descriptive tools and regression of trend equations in time variables. Also, annual compound growths were calculated while the existence of acceleration, deceleration, or stagnation was verified by estimating quadratic equations in time trend variables. Results revealed that while the trends in both output and area devoted to sweetpotato were increasing, that of yield was decreasing. A statistically significant positive association ($r = 0.99$; $p<0.01$) was found between output and area while statistically significant negative associations existed between output and yield ($r = -0.71$; $p<0.01$) and area and yield ($r = -0.72$; $p<0.01$). Estimated trend equations for the 1961-2007 aggregate data revealed statistically significant increases or growths for output and area but a statistically significant decrease for yield. Compound growth rates for the aggregate data were calculated to be 7.86% for output, 11.52% for land area, and -3.28% for yield. When acceleration, deceleration, or stagnation was assessed, results also revealed the existence of a statistically significant acceleration for output ($p<0.01$) and land area ($p<0.01$) but a significant deceleration for yield ($p<0.05$). The conclusion drawn from the study is that the growth recorded in output during the study period was mainly accounted for by an increase in land area rather than an increase in the yield of sweetpotato. Conscious investments in innovations, funding of research for development and the dissemination of appropriate technologies, the development of rural infrastructures, and guaranteed access to production inputs and appropriate marketing channels for farmers would, among other things, be used to promote the yield and production of sweetpotato in Nigeria.

Keywords: *Ipomoea batatas,* production, land area, yield, acceleration, deceleration, stagnation, growth, Nigeria.

Introduction

Sweetpotato [*Ipomoea batatas* (L.) Lam] is an important food security crop that feeds millions of people in the developing world. The crop is very popular among farmers with limited resources and produces more biomass and nutrients/ha than any other food crop in the world (Prakash 1994). It also has high nutritional energy qualities and its leaves can be consumed as vegetables (Fawole 2007, Chukwu 1999). Furthermore, it has been reported that sweetpotato could be a good source of vitamins A, C, and E, dietary fiber, potassium, and iron, and is low in fat and cholesterol (Answers.com 2008).

In Nigeria, sweetpotato ranks fourth among the major root and tuber crops produced (Tewe et al 2003), taking a place after cassava (*Manihot esculenta*), yam (*Dioscorea* spp.), and cocoyam or taro (*Xanthosoma* sp., *Colocasia sp.*). Among the factors accounting for its increasing importance in the nation's farming and food systems are that it is relatively easy to grow, matures easily, and has enormous industrial and economic potentials (Fawole 2007). Also, in their investigation of profitability in the use of the sweetpotato crop as a soil conservation strategy, Ogbonna et al (2007) found that the crop can be profitably used when conserving farmland and recommended that farmers be encouraged to go into sweetpotato farming. Notwithstanding the well-known importance and potentials of sweetpotato as a food security crop and potential foreign exchange earner for Nigeria, there tends to be gross inefficiency in the allocation of resources in the production of the crop. Taking available land resources as a test case, there seems to be an inverse relationship between production and yield (Fig. 1). The figure shows that whereas the quantity produced and area cultivated tend to increase over time, suggesting a positive association between them, the yield tends to show a decreasing trend. There is a need to conduct a scientific investigation on this observed trend. The general objective of this study is to analyze the trends in production, yield or productivity, and land area devoted to sweetpotato in Nigeria. The specific objectives are to determine if the output, area, and yield have grown or reduced over time, to calculate the growth rates, and to deduce if there had been acceleration or deceleration or stagnation in the growth of these variables. Consequently the hypotheses to be tested are that there was a significant acceleration in the growth of a) output of sweetpotato; b) area devoted to sweetpotato; and c) yield of sweetpotato, each against the null hypotheses that there was either deceleration or stagnation at different periods from 1961–2007. The result of the study is expected to aid researchers, policy makers, and relevant agencies of government in their planning, and research and development efforts towards the development and use of sweetpotato to attain food security.

Materials and Method

Data source. Secondary data were used for the study. The time series data, which covered the period 1961–2007, were collected from the Statistics Division of the Food and Agriculture Organization (FAO 2008). The national series data, such as those from the Central Bank of Nigeria (CBN) or any other relevant agency could alternatively have been used. However, it is common to find differences in such data series from different sources (Manyong and Nokoe 2003) while the existing data were not available over the 1961–2005 period covered by this study. Principally, this explains our reliance on the FAO data. The graphical presentation of the trends in production, cultivated land area, and yield is already presented (Fig. 1).

Modeling trends for analysis of growth rate in soybean. The exponential, also called the log-linear trend or left-side semi-log analysis (Studenmund 2001), was used to model the growth trends in sweetpotato production in Nigeria. This follows Diebold (2007) as it has been variously applied (Udom 2006, Onyenweaku and Okoye 2005, Ojiako et al 2007, Ojiako et al 2008). The exponential trend equation for the output, yield, and area devoted to sweetpotato is specified as

$$Q_{spi} = \exp(b_0 + b_1 t_i + \varepsilon_i) \qquad (1)$$

where Q_{spi} is either volume of production or area of land or yield of sweetpotato at year *í* measured in tonnes for output, tonnes/ha for yield, and hectares for land area, t_i is the time trend measured in years, β_0 is the intercept or constant of the trend equation, β_1 is the slope or trend coefficient, and ξ_t is the error term. If linearized by taking the natural logarithm of both sides, equation (1) becomes

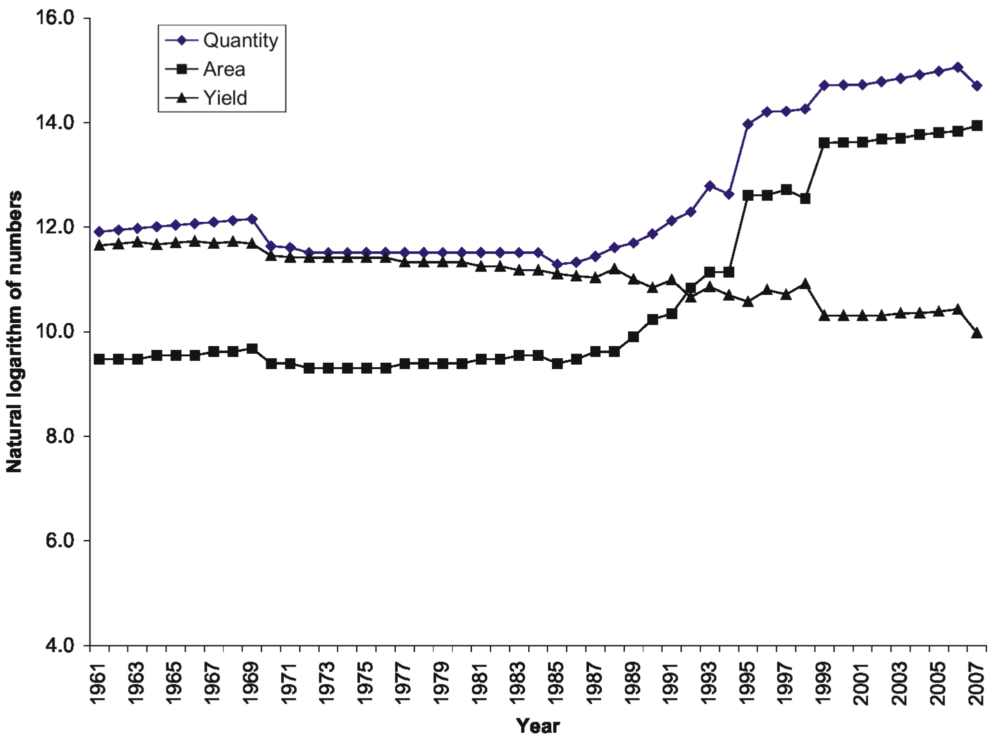

Figure 1: Graphical presentation of trends in quantity, area, and yield of sweet potato, 1961–2007

$$\ln Q_{spi} = \beta_0 + \beta_1 t_i + \xi_t \quad (2)$$

Where ln Q_{spi} is the natural logarithm of the relevant variables, and all other variables are as previously defined.

From equation (2) the annual exponential growth rate (g) of sweetpotato output, area or yield, when increases by one year can be expressed following Onyenweaku and Okoye (2005) and Ojiako and Olayode (2008) as

$$g = (e^{\beta_1} - 1) * 100\% \quad (3)$$

where g = growth rate and $e = 2.71828$ is the Euler's exponential constant (Sawant 1983).

To ascertain the growth pattern, and consequently test the hypothesis of whether there existed acceleration or stagnation or deceleration in growth of sweetpotato production, area and yield, the quadratic equations in the time trend variables were fitted to the data for the six periods covered in the analysis. The quadratic equation is specified as

$$\ln Q_{SPi} = \beta_0 + \beta_1 t_i + \beta_2 t_i^2 + e_i \quad (4)$$

where the variables lnQ_{SP} and t are as previously defined and β_0, β_1 and β_2 are unknown parameters to be estimated.

In the specification in expression (4), the linear and quadratic time variables indicate the circular path in the dependent variable (Q_{SP}) while the quadratic term (t^2) allows for the possibility of acceleration or deceleration or stagnation in growth during the period under study (Sawant 1983, Onyenweaku and Okoye 2005). In testing the specified hypotheses, our major interest is on the coefficient of t^2 (β_2), which is a measure of the pattern of growth. If β_2 is positive and statistically significant there is acceleration in growth, if β_2 is negative and statistically significant there is deceleration in growth, if β_2 is positive or negative but not statistically significant there is stagnation in the growth process (Onyenweaku and Okoye 2005, Anyaegbunam et al 2006).

For this study, five different periods were considered to enable comparison of the influence of the various economic and political development policies on growth trends of sweetpotato: the first decade following political independence (1961–1970) during which the nation survived a thirty-month Civil War; the second decade following independence (1971–1980), which was the post-Civil War era of recovery, reconciliation and reconstruction; the third decade of political independence (1981–1990) during which the nation had a failed Second Republic and experimented different measures of economic restructuring, including the Austerity Measures introduced in April 1982 and the Structural Adjustment Programme (SAP) introduced in July 1986 respectively; the fourth decade following political independence (1991–2000) that witnessed the highest level of social, economic and political instability but which later culminated in the enthronement of democratic rule in May 1999; and the 2001–2007 era of democratic rule and full liberalization. Finally the aggregated data for 1961–2007 periods were analyzed to get the general picture. All analyses were done using Standard E-views Software.

Results and Discussion

Descriptive statistics of output, area and yield of sweetpotato. The mean and standard deviation (in parentheses) of the production output, cultivated land area, and yield of sweetpotato are presented in Table 1 for the different time periods covered by this study. For output, the average level was 0.164 million metric tonnes during the 1961–70 period. This dropped by 38.26% to 0.101 million metric tonnes during the 1971–80 period. The recorded average output for the 1981-90 period was 0.102 million metric tonnes or a decrease of 37.10% over the 1961–70 period. Output increased substantially to an average of 1.17 million metric tonnes during the 1991–2000 period. This represented increases of 614.18% and 1035.47% respectively over the 1961–70 and 1981-90 periods. The average output recorded for 2001-2007 represented increases of 1738.72% and 157.46% respectively over the averages for the 1961–70 and 1991–2000. The average annual output of sweetpotato for the entire 1961–2007 period was calculated as 0.775 million metric tonnes, which was 485.64% higher than the average recorded in the first two decades (1961–1980) but 45.68% lower than the 1.4 million metric tonnes annual average recorded in the following twenty-seven years (1981–2007).

Table 1 also shows that aside from the initial 17.27% decrease in average area cultivated during the 1971–80 over the base 1961–70 period, continuous increases of 12.95%, 2112.37% and 6672.87% respectively were recorded in the 1981–90, 1991–2000 and 2001–2007 over the base period. The average cultivated area for the 1961–2007 aggregate data was 214, 387 hectares. In the case of yield the annual averages, given as 11.73 t/ha during 1961-70, fell continuously to 8.79 t/ha in

1971–80, 6.74 t/ha in 1981–90, 4.47 t/ha in 1991–2000 and 3.18 t/ha in the 2001–2007 periods. These reflect average decreases of 25.02%, 42.58%, 61.93% and 72.86% respectively over the annual average for the 1961–1970 periods. Thus it follows that while the trends in both output and area of sweetpotato were increasing that of yield was decreasing. This finding was corroborated further by the correlation matrix presented in Table 2. Output and area cultivated are positively associated ($r = 0.99$) while negative associations were calculated for output and yield ($r = -0.71$) and area and yield ($r = -0.72$). All correlation coefficients are highly significant ($p<0.01$).

Analysis of trend equations for output, land area and yield of sweetpotato. The estimated trend equations for sweetpotato output are presented in Table 3 for the different time periods under consideration. The results show that the coefficients of the time trend were positive for all periods, except for 1971–1980 when the coefficient was negative. The slope coefficients were statistically not significant for the 1961–1970, 1971–1980 and 1981–1990 periods. This means that sweetpotato production remained the same during the periods. However, the coefficients were statistically significant ($p<0.01$) for 1991–2000 and 2001–2007 periods as well as for the aggregated data (1961–2007) signifying increase in production. The regression equations also had good fit with $r^2 = 0.592$ and $F = 65.18$ for 1961–2007, $r^2 = 0.903$, $F = 74.62$ for 1991-2007, and $r^2 = 0.985$ and $F = 367.43$ for 2001–2007. Since the slope coefficients were positive for these periods, it means that significant increases or growth were recorded during those periods.

The trend equations for land area devoted to sweetpotato are presented in Table 4. The results reveal similar trend as was the case for output. The equations have good fit for the 1981–1990 ($r^2 = 0.57$; $p<0.05$), 1991–2000 ($r^2 = 0.91$; $p<0.01$), 2001-2007 ($r^2 = 0.97$; $p<0.01$) and the aggregate data of 1961-2007 ($r^2 = 0.72$; $p<0.01$). The slope coefficients were positive and statistically significant implying that significant increases or growths were achieved during those periods. Similar conclusion could not be drawn for the 1961–1970 and 1971–1980 periods when the area cultivated remained the same.

The estimated yield trend equations are presented in Table 5. Like the case for output and area grown, yield did not witness statistically significant change during the 1961–1970 periods. However significant decreases were observed during the 1971–80, 1981–1990 and 1991–2000 periods as depicted by the negative signs of the slope coefficients. Significant growth was only achieved during the last seven years (2001–2007). The estimated equation for the aggregate dataset for 1961–2007 also produced a statistically significant negative sign for the slope coefficient, implying significant decrease in yield. All the estimated yield trend equations have good fit, except for the 1961–70 periods.

Growth rate of output. The computed annual compound growth rates in sweetpotato output, land area and yield are presented in Table 6. The output grew at a compound rate of 0.02% during the first decade of political independence (1961–1970). It slumped to an annual rate of -0.52% during the second decade (1971–1980) but picked up again during the third decade (1981–1990) when annual compound growth rate of 2.95% was recorded. None of the aforementioned growth rates was statistically significant. However, statistically significant annual compound growth rates were achieved during the fourth decade (1991–2000) and the last seven years of political independence, 2001–2007, when 37.59% and 6.33% respectively were attained. Equally statistically significant annual compound growth rate of 7.86% was attained in the aggregate data for 1961–2007.

For the cultivated land area, the growth rates were calculated as 1.01% for 1961–1970, 0.79% for 1971–1980, 6.61% for 1981-1990, 44.47% for 1991-2000, and 3.91% for 2001–2007 periods. For the aggregate 1961–2007 period, the compound growth rate was calculated as 11.52%. Positive growth was realized for each period. A comparison with calculated growth rates for output shows that, although the two follow similar trend, higher growths were recorded for land area in all the studied periods, except for 2001–2007, when growth rate in output was 6.33% as against 3.91% for land area.

A more severe case was observed in yield. The growth rate dropped persistently from -0.98% in 1961–1970 to -1.30% in 1971–1980, -3.43% in 1981–1990, and further to -4.76% in 1991–2000. The aggregate data for 1961–2007 produced an annual compound growth rate calculated as -3.28%. Although the rate for 2001–2007 periods is significant and positive, this could be temporary and deceptive as to reflect the true situation.

Confirmation of acceleration, deceleration, or stagnation in output growth. The existence or otherwise of acceleration, stagnation or deceleration in growth of sweetpotato output, land area and yield was ascertained using the quadratic equations in the time trend variables earlier expressed in equation (4). The results for output are presented in Table 7. Besides the output equation for 1961–1970 all other equations has good fit as shown by the r^2 and significance of F-values. The slope coefficients for t^2 is negative for the 1961–1970, 1991–2000 and 2001–2007 time periods and positive for the 1971–1980, 1981–1990 and 1961–2007 periods. However, the coefficients were only significant for 1981–1990 and 1961–2007 periods. The significant positive values of the coefficient of t^2 for 1981-1990 and 1961–2007 are confirmation of statistically significant acceleration during the two periods. None of the investigated periods confirmed significant deceleration, rather stagnation in output was recorded for sweetpotato during the 1961–1970, 1971–1980, 1991–2000 and 2001–2007 periods.

The results for cultivated land area are presented in Table 8. Like in the case of output, all equations have good fit except for the 1961–1970 period. Also, existence of statistically significant acceleration was confirmed for the 1981–1990 and 1961–2007 periods and stagnation was confirmed for the rest of the investigated periods.

The equations have good fit for all time periods, except for 1991–2000. Statistically significant negative values were calculated for the coefficients of t^2 for the aggregate data (1961–2007) as well as for the 1961–1970 periods. The results are confirming existence of significant deceleration in yield growth during the periods. The rest of the investigated time periods confirmed existence of stagnation in yield growth.

Summary and Conclusion

We have examined the trends in output, land area, and yield or productivity of sweetpotato in Nigeria since the nation's political independence with a view to determining the existence of acceleration, deceleration or stagnation in growth of the variables overtime. The results reveal that there was a strong positive association between sweetpotato production and land area devoted to the crop. Also revealed was a strong negative association between outputs and yield, on the one hand, and yield and area, on the other. When the entire 1961–2007 time period was considered, it was found that the output of sweetpotato increased substantially. However, the growth recorded in output within the period was mainly accounted for by increase in land area cultivated, rather than increase in yield of the crop.

However, investigation of the different time periods showed that they were characterized by either stagnation or deceleration in productivity even as both output and area might have increased. Similar findings were reported by Onyenweaku and Okoye 2005 in their investigation of trends in cassava, another important food security crop in Nigeria. Even at that, growth in area devoted to sweetpotato production at different periods of time exceeded the growth in output, implying that there has been high level of inefficiency in the use of land resources. Specifically, the yield per hectare showed significant and persistent decrease within the three decades between 1971 and 2000, resulting to decrease in the aggregate productivity performance.

The study showed further that significant acceleration in growth of output and area cultivated was only achieved during the 1981–1990, which was the period when the Structural Adjustment Programme (SAP) was initially introduced and implemented in Nigeria. This is in disagreement with the observed significant deceleration in output reported by Ojiako et al 2008 in the case of livestock during the SAP era in Nigeria. The observed acceleration in growth for sweetpotato during the SAP era could be attributed to the price incentives provided to farmers under the liberalization policy adopted at the time. It is regrettable though that the gains could not be sustained due largely to political instability and associated policy distortion, lack of political will, infrastructural decay and inadequate funding of research for development of the crops sector.

The implication of the foregoing findings is that the effort to achieve the desired expansion of sweetpotato should be directed towards improvement in productivity rather than mere expansion in production. This would require conscious investments in chemical, mechanical as well as organic or biological innovations, which would be beneficial to sweetpotato as a crop. Appropriate political will is required towards developing our rural infrastructures and funding of research to ensure the development of appropriate technologies, including use of improved sweetpotato varieties, productive agronomic practices, optimal post-harvest utilization options, and appropriate extension services that would ensure timely dissemination of such technologies and relevant information to farmers. Also there is need to guarantee improvement in the farmers' access to production inputs like land, credit, fertilizer, irrigation facilities as well as appropriate marketing channels for their products.

Table 1: Descriptive statistics of quantity produced, land area and yield of sweet potato, 1961-2007

Variable	1961-70 (n=10)	1971-80 (n=10)	1981-90 (n=10)	1991-2000 (n=10)	2001-2007 (n=7)	1961-2007 (n=47)
Quantity (tonnes)	163600.0	101000.0	102900.0	1168400.0	3008143.0	774808.5
	(22152.00)	(3162.278)	(18266.24)	(879487.4)	(397704.0)	(1114842.0)
Area (ha)	13900.00	11500.00	15700.00	307520.0	941428.6	214387.2
	(1197.219)	(527.0463)	(4854.551)	(294909.5)	(78202.42)	(355542.3)
Yield (t/ha)	11.731	8.795	6.736	4.466	3.184	7.225
	(0.864)	(0.398)	(0.825)	(0.982)	0.163)	(3.106)

Values in parentheses are the standard deviations

Table 2: Correlation matrix for quantity produced, land area and yield of sweet potato, 1961-2007

Variable	Quantity	Area	Yield
Quantity	1.000000	-	-
Area	0.991631***	1.000000	-
Yield	-0.712379***	-0.716379***	1.000000

***=significant at 1%; **=significant at 5%

Table 3: Estimated trend equations for Nigeria's sweet potato output, 1961-2007

Period	Estimated parameters		r^2	F-value	Sig.	D-W
	β_0	β_1				
1961-1970 (n=10)	11.99482***	0.000185				
	(111.1329)	(0.010608)	0.000014	0.001	0.976	1.355
1971-1980 (n=10)	11.55105***	-0.005199				
	(620.2316)	(-1.732051)	0.272727	3.000	0.122	1.402
1981-1990 (n=10)	11.36855***	0.029036				
	(108.5221)	(1.719821)	0.269925	3.139	0.114	0.618
1991-2000 (n=10)	11.83685***	0.319091***				
	(51.65699)	(8.640481)	0.903216	74.616	0.000	1.795
2001-2007 (n=10)	14.66389***	0.061338***				
	(979.8784)	(18.33024)	0.985337	367.427	0.000	2.155
1961-2007 (n=47)	10.7523***	0.075702***				
	(41.61582)	(8.077367)	0.591814	65.179	0.000	0.077

***=significant at 1%; **=significant at 5%; t-values are in parentheses.

Table 4: Estimated trend equations for area cultivated of sweet potato in Nigeria, 1961-2007

Period	Estimated parameters		r^2	F-value	Sig.	D-W
	β_0	β_1				
1961-1970 (n=10)	9.481131***	0.010034				
	(162.7454)	(1.068670)	0.124923	1.16	0.312	1.713437
1971-1980 (n=10)	9.305651***	0.007910				
	(328.3928)	(1.732051)	0.272727	3.000	0.122	1.409
1981-1990 (n=10)	9.276187***	0.063956**				
	(76.18510)	(3.259216)	0.570412	10.719	0.011	0.750696
1991-2000 (n=10)	10.09556***	0.367871***				
	(40.66813)	(9.194964)	0.913558	84.453	0.000	2.331059
2001-2007 (n=10)	13.59881***	0.038334***				
	(962.4862)	(12.13381)	0.967155	171.602	0.000	1.769321
1961-2007 (n=47)	8.077251***	0.109004***				
	(29.34068)	(10.91584)	0.725870	119.08	0.000	0.093861

***=significant at 1%; **=significant at 5%; t-values are in parentheses.

Table 5: Estimated trend equations for yield of sweet potato in Nigeria, 1961-2007

Period	Estimated parameters		r^2	F-value	Sig.	D-W
	β_0	β_1				
1961-1970 (n=10)	11.72402***	-0.009849				
	(217.7464)	(-1.13502)	0.138698	1.347	0.279	1.221514
1971-1980 (n=10)	11.45574***	-0.01311***				
	(696.7987)	(-4.94747)	0.753675	25.000	0.001	1.443410
1981-1990 (n=10)	11.30270***	-0.03492***				
	(213.3652)	(-4.09021)	0.676504	17.352	0.003	1.865930
1991-2000 (n=10)	10.95162***	-0.048781**				
	(83.65311)	(-2.311969)	0.400534	5.298	0.050	2.113704
2001-2007 (n=10)	10.27542***	0.023001***				
	(931.0079)	(9.320065)	0.945571	80.000	0.000	2.816718
1961-2007 (n=47)	11.88537***	-0.03330***				
	(327.0583)	(-25.26408)	0.934141	640.743	0.000	1.256023

***=significant at 1%; **=significant at 5%; t-values are in parentheses.

Table 6: Exponential growth rates in sweet potato output, area, and yield for Nigeria's, 1961-2007

Period	Output		Land area		Yield	
	Parameter (β_1)	Exponential Growth	Parameter (β_1)	Exponential Growth	Parameter (β_1)	Exponential Growth
1961-1970 (n=10)	0.000185	0.018502	0.01003	1.008	-0.00985	-0.980
1971-1980 (n=10)	-0.005199	-0.51855	0.00791	0.794	-0.01311***	-1.302
1981-1990 (n=10)	0.029036	2.946165	0.06396**	6.605	-0.03492***	-3.432
1991-2000 (n=10)	0.319091***	37.58765	0.36787***	44.466	-0.04878**	-4.761
2001-2007 (n=10)	0.061338***	6.325823	0.03833***	3.908	0.02300***	2.327
1961-2007 9n=47)	0.075702***	7.864109	0.10900***	11.517	-0.0333***	-3.275

***=significant at 1%; **=significant at 5%

Table 7: Estimated quadratic equations in time variables for Nigeria's output of sweet potato, 1970-2007

Period	Estimated parameters			r^2	F-value	Sig.	D-W
	β_0	β_1	β_2				
1961-1970 (n=10)	11.71558***	0.139804	-0.012693	0.425957	2.789	0.129	1.757
	(77.83618)	(2.223996)	(-2.279042)				
1971-1980 (n=10)	11.59870***	-0.029026**	0.002166	0.575758	4.750	0.050	1.776
	(443.0242)	(-2.654637)	(2.236068)				
1981-1990 (n=10)	11.72447***	-0.148921***	0.016178***	0.806206	15.105	0.003	1.492
	(118.0221)	(-3.589411)	(4.401236)				
1991-2000 (n=10)	11.40067***	0.537183**	-0.019827	0.925533	43.690	0.000	2.283
	(30.81675)	(3.476761)	(-1.448386)				
2001-2007 (n=7)	14.63597***	0.079951***	-0.002327	0.989590	199.895	0.000	2.387
	(563.0398)	(5.366862)	(-1.278388)				
1961-2007 (n=47)	12.53273***	-0.142313***	0.004542***	0.904983	209.905	0.000	0.317
	(64.50314)	(-7.621563)	(12.04248)				

***=significant at 1%; **=significant at 5%; t-values are in parentheses

Table 8: Estimated quadratic equations in time variables for area of land devoted to sweet potato in Nigeria, 1970-2007

Period	Estimated parameters			r^2	F-value	Sig.	D-W
	β_0	β_1	β_2				
1961-1970 (n=10)	9.360084***	0.070557	-0.005502	0.365337	2.185	0.183	1.994163
	(102.5000)	(1.850048)	(-1.628386)				
1971-1980 (n=10)	9.378160***	-0.028345	0.003296	0.575758	4.750	0.050	1.566234
	(235.4237)	(-1.703722)	(2.236068)				
1981-1990 (n=10)	9.685890***	-0.140895**	0.018623***	0.879937	25.000	.001	1.462665
	(81.75345)	(-2.847466)	(4.248084)				
1991-2000 (n=10)	9.805799***	0.512750**	-0.013171	0.921052	40.814	0.000	2.520354
	(22.45662)	(2.811660)	(-0.815182)				
2001-2007 (n=7)	13.56084***	0.063647***	-0.003164	0.986922	136.832	0.000	2.734317
	(737.8216)	(6.042584)	(-2.45885)				
1961-2007 (n=47)	9.964464***	-0.12208***	0.004814***	0.934011	311.637	0.000	0.376830
	(47.33157)	(-6.034171)	(11.78064)				

***=significant at 1%; **=significant at 5%; t-values are in parentheses.

Table 9: Estimated quadratic equations in time variables for yield of sweet potato in Nigeria, 1970-2007

Period	Estimated parameters			r^2	F-value	Sig.	D-W
	β_0	β_1	β_2				
1961-1970 (n=10)	11.56583***	0.069247**	-0.007191**	0.611827	5.732	0.034	1.739102
	(173.8443)	(2.492185)	(-2.920966)				
1971-1980 (n=10)	11.43088***	-0.000680	-0.001130	0.789512	13.266	0.004	1.705087
	(408.6473)	(-0.058180)	(-1.091697)				
1981-1990 (n=10)	11.24892***	-0.008027	-0.00245	0.697726	8.390	0.014	1.887704
	(119.3520)	(-0.203936)	(-0.701032)				
1991-2000 (n=10)	10.80520***	0.024431	-0.006656	0.448254	2.817	0.127	2.302919
	(46.74047)	(0.253048)	(-0.778091)				
2001-2007 (n=7)	10.28549***	0.016291	0.000839	0.949344	35.091	0.003	3.012157
	(468.5791)	(1.295008)	(0.545814)				
1961-2007 (n=47)	11.77860***	-0.02023***	-0.00027**	0.943326	368.642	0.000	1.459661
	(224.1661)	(-4.006108)	(-2.67038)				

***=significant at 1%; **=significant at 5%; t-values are in parentheses.

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