IITA
Research to Nourish Africa

CGIAR

Standard Operating Protocol for Yam Variety Performance Evaluation Trial

Asrat Asfaw

www.iita.org

Standard Operating Protocol for Yam Variety Performance Evaluation Trial

Asrat Asfaw

Published by the International Institute of Tropical Agriculture (IITA)
Ibadan, Nigeria

IITA is the lead research partner facilitating agricultural solutions for hunger and poverty in the tropics. It is a member of the CGIAR Consortium, a global research partnership that unites organizations engaged in research for sustainable development for a food secure future.

International address:
IITA, Grosvenor House,
125 High Street
Croydon CR0 9XP, UK

Headquarters:
PMB 5320, Oyo Road
Ibadan, Oyo State

ISBN 978-978-8444-68-8

Correct citation: Asfaw, A., editor. 2016. Standard Operating Protocol for Yam Variety Performance Evaluation Trial. IITA, Ibadan, Nigeria. 27 pp.

Cover photo: by Asrat Asfaw taken at EDITS-Yam field of JIRCAS in 2015.

Contents

Figures

Acknowledgments

This SOP for yam field performance evaluation is compiled from contributions by yam community of practice members Dr David De Koeyer, Dr Lava Kumar, Dr Olufisayo Kolade and Dr Antonio Lopez-Montes of IITA, Dr Amani Kouakou of CNRA, Côte d'Ivoire, Dr Emmanuel Chamba of CSIR-SARI, Ghana, Dr Emmanuel Otoo of CSIR-CRI, Ghana, Drs Jude Obidiegwu and Emmanuel Nwachukwu of NRCRI, Nigeria and Professor Alexandre Dansi of UAC, Benin. The financial support from the Bill & Melinda Gates Foundation for the AfricaYam project is highly appreciated.

Introduction

The development and delivery of superior varieties that squarely meet the needs and preferences of growers and consumers is the ultimate goal of any breeding program. This requires careful assembly of germplasm of interest and testing them in a series of trials in specific target environments. The AfricaYam project is conducting yam variety selection and evaluation trials in four target countries in West Africa: Benin, Côte d'Ivoire, Ghana, and Nigeria. Each country has researchers and scientists to monitor breeding advances and varietal evaluation. Ensuring quality data from such field evaluation and selection trials requires a standardized protocol. This protocol presents basic guidelines for setting-up field evaluation trials of advanced yam clones and data recording to assist IITA and NARS staff in such a way that standardized field trials can be set-up, trial conditions accurately characterized, and quality data can be recorded, collected, shared, centrally stored, and uploaded to the YamBase and other trial data management systems. The protocol attempts to provide common ground for breeders and selectors (i) to accurately characterize environmental conditions and assess seasonal biotic factors during the planting season, (ii) agree on the key traits to be assessed and measured, (iii) to apply standardized procedures and formats to record data, and (iv) develop a user-friendly and practical system to upload, store, and share data.

Definitions

- Trait = a distinguishing quality or characteristic. Visible or observable quality genetically determined or conditioned. It is an entity + attribute. Example: Flower + color = Flower color (trait).
- Phenotype = observed physical appearance or biochemical characteristics. Entity + attribute + value. Example:- Leaf + color + red = leaf color red = phenotype (observed)
- Genotype = a collective term used by breeders to refer to a group of varieties, cultivars, wild relatives, and landraces to be studied or evaluated.
- Germplasm = all the plant accessions (a single, collected variety or cultivar or a wild plant, a landrace or a bred cultivar) of a crop available for plant breeding.
- Clone = a group of similar individuals arising from vegetative propagation or asexually from one ancestor or stock to which they all are genetically identical or having the same genetic constitution.
- Variety = a group of individuals within a species which are distinct in form or function from other similar arrays of individuals.
- Environment = sum total of surrounding factors that affect growth and development of a plant. Environment in variety trial could be total of external conditions affiliated with location, year/season, management practice, or a combination of such conditions.
- Pedigree = a record of the ancestry of an individual or family.

Goal of Variety Performance Evaluation Trials

3

Conducting a variety performance trial is a demanding process requiring a sequence of operations and preparation. Its overall goal is to identify differences among the test varieties/clones under near “ideal and perfect” conditions for the intended purpose that permit the expression of the genetic potential of the plant. A variety trial could be carried out on a designated research site, what we call on-station, or it can be done under farmers’ field conditions (on-farm). Prior to embarking on variety performance evaluation trials, the following series of questions need to be addressed. Asking these questions on a regular basis helped us stay focused on the task at hand while ensuring its proper and timely implementation.

- What will/must I do?
- Why am I doing it? What is the driving purpose? What do I desire to achieve?
- How will I do it? What must I have at hand so I can do it? When will I have to do it?
- What planning process and calendar of activities must I have in place for successful implementation?
- Can I personally do all of the tasks? Will I be able to do all the tasks? Should I delegate some of the tasks?
- Who will assist me in doing it? Is there a support group that enables me to do the things I must do; to do them well; to do them on time?
- Are all the tasks in my area of expertise? If not, who is there? Who is designated as the one who will do this work?

Analyzing these questions will lead to identification of tasks that must be done by you or your team or by those trained to do them so that the work will succeed. The tasks for variety trial or any other breeding activities have to be done in a timely manner and in proper sequence. Planning the variety evaluation trial encompasses: stating a clear objective, selection of treatment, choice of experimental design, number of replications, selection of site, measuring soil heterogeneity, considering competing effects, plot labeling, and preparing the proper field book for the trial.

Setting Variety Trials

4

Variety performance evaluation in yam could follow a sequence of trials namely; a preliminary or observation trial, advanced multilocation and multi-season trial, and a variety verification or demonstration trial depending on the variety testing procedure of the target country. Based on the nature of the yam crop, variety evaluation trials could be initiated using up to thirty (30) elite clones recommended by breeding programs that have already shown superior performance in trials that targeted specific traits. However, the number of clones to evaluate at different stages or types of the trials is influenced by the objective, resources, and human capacity.

During the first evaluation season, the preliminary/observation trials are often established in a location representative of the target production area. However, number of locations and replications per location for the preliminary trial depends on the quantity and quality of planting material (seed yam) available for the test genotypes. Most often the preliminary trial is planted on an experimental station and carefully monitored by researchers and experienced technicians. At this stage, the newly developed or introduced test clones are compared with existing check varieties for their observable merits for agronomic, biotic or abiotic stress tolerance, and quality traits before promoting them to extensive multilocation and multi-season testing. From the second season onwards, advanced variety trials could be planted in more than one location either on-station or on-farm or under different management practices representative of the target production environments to fairly assess the test varieties' quality and performance in relation to the check or standard varieties and identify the best variety for release. The number of seasons and locations to execute the preliminary or advanced variety trials depends on the countries' variety testing procedures and requirements. The variety verification or demonstration trial is normally conducted under real farmer conditions and on-station using a few identified candidate varieties from advanced trials that meet high standards for quality and performance for release decisions and/or promotion for use by growers. Such trials create opportunities for communication and interaction with various stakeholders on values of new varieties to be promoted for large-scale production.

Planting Materials

Assemble elite clones or varieties from IITA and/or national breeding programs that have shown superior performance for key traits in previous trials as test genotypes. In addition, include at least two most preferred varieties in a target production environment as a local check and one widely grown variety across sites as a standard check. For all the test clones and check varieties, high-quality seed tubers from the same origin should be used. The preliminary variety trial in the first season requires at least 10 seed tubers (setts) per entry (5 plants per row), to be planted in two replications in one location. From the second season onwards, the plot size and number of locations should be increased depending on planting material availability. The second season and advanced variety trial requires a 5 m by 4 ridge plot to accommodate 20 plants per plot. In the advanced variety trial, the six middle plants constitute the net plot while the fourteen outer plants are the border rows. Depending on the number of replications set for the trial and number of locations to plant the trial, one has to prepare in advance a sufficient quantity of seed tubers (setts) for the test genotypes and check varieties to execute a standard yield trial.

Preparing planting material: The tuber is the most important planting material used for the variety performance trial. The planting material from a tuber is called a “sett”. A sett size for standard variety performance trials should be between 200 and 250 grams. Seed tubers for planting could either be small, healthy whole tubers or larger tubers cut into mini-setts and pre-treated for disease or pest damage. From a larger tuber generally three types of mini-setts could be obtained (Fig. 1):

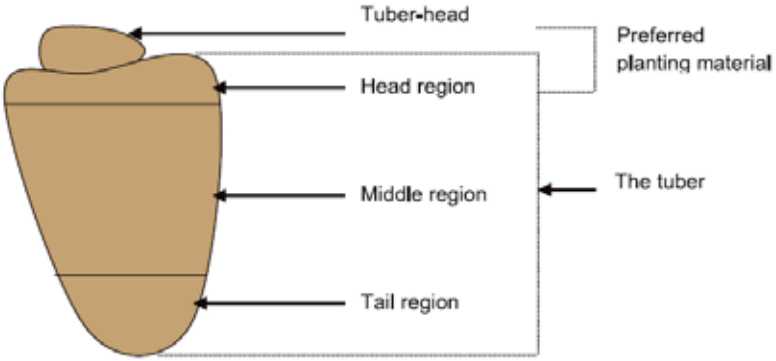

Figure 1. Section of whole tuber (Hamadina 2011).

- Head setts: best yam setts to plant. It emerges fast (develop new shoots fast) because of the presence of the primary nodal complex (eye) which gives rise to the new plant.
- Middle setts
- Tail setts

While preparing setts from large whole tubers, proper seed cutting practices should be followed to prevent disease spread between tubers and clones. Disinfect the tools after each cutting by dipping in a 5% (v/v) sodium hypochlorite solution (common bleach such as JIK available in grocery stores can be used) for at least 5 min, followed by rinsing by dipping tools in tap water. However, instead of using setts from larger tuber cuttings, plan to have a separate seed multiplication plot in a previous year or season using the mini-sett technique to produce a sufficient quantity of clean, small-seed-size, whole tubers. Having a separate seed multiplication plot for the genotypes under trial should be a routine practice for the yam variety performance evaluation exercise. When setts are used as planting material, it is advised to plant setts from the head, middle, and tail portions in separate plots to account for variation in germination timing and rates, and it also eases agronomic management. In addition, the record of the weight of the setts planted per plot should be taken to correct variability arising from planting different size setts during data analysis.

Pre-treatments before planting: Treat the planting setts with fungicide and insecticide at storage and before planting to encourage wound healing and prevent entry of pathogenic organisms on cut surfaces that could spoil the setts. Treat seed tubers (mini-setts or small tubers) with a mixed solution of a pesticide cocktail prepared as follows:

- Macozeb: 70 g
- Chlorpyrifos: 75 ml
- Tap Water: 10 L

Place seed tubers (setts) from the same genotype/entry in a properly labelled net bag and dip it into the solution for 10 minutes, and then leave them in a shaded place (e.g., under a tree) for 18 to 24 hours to allow the cut surface

to dry. Make sure that the seed tubers of each genotype are properly bagged and labelled to avoid mix-up and misnaming during the treatment and drying process. Use a permanent label (permanent marker, pencil, or barcode label) that will not fade in the treatment solution and drying process.

To ensure quality data from field trials, use **uniform size** and **pre-germinated** setts. This requires proper planning in the previous season to produce a sufficient quantity of clean tubers for the genotypes and generate excess setts. Use of excess setts would account for variation in germination rates to enable planting at the same time. Pre-germination of the planting setts could be done using pots or germination chambers/ boxes under screen house/shade-nets or small raised seedbeds in the field under conditions favorable for sprouting. Use moist carbonized rice husk or other media like sawdust, coconut coir etc. available locally for the pre-germination exercise. Use proper labelling and isolation to avoid mix-up and misnaming of the genotypes during pre-germination and the field planting process. When there is enough seed yam and the program presumes pre-sprouting is not practical under certain circumstance, use the same portion of the tubers for planting, preferably the head portion as it sprouts and emerges more readily after planting than the non-head setts. However, it should be noted that planting unsprouted head setts could result in variation in emergence within a plot and this has to be accounted for during data analysis by taking a record of the emergence date of plants within a plot.

Experimental Design

Depending on the condition of the site and number of genotypes/entries to be evaluated, a researcher at each site has to make their own choice of the most appropriate experimental design for the site. If the experimental plot at the trial site has unidirectional heterogeneity, a Randomized Complete Block Design (RCBD), where replications of clones planted in blocks and within each block all genotypes are randomized is the most preferred design. Alpha designs are suitable designs to handle larger numbers of clones. Please refer to any experimental design and analysis books on conditions of using respective field designs. For instance, in RCBD, all treatments (test clones/check varieties) are grouped into uniform blocks of equal size. The main purpose of blocking is to reduce experimental error by

eliminating sources of heterogeneity such as soil fertility or field slopes. With a predictable pattern of field variability, plot shape and block orientation can be carefully chosen so that the experimental conditions within each block are as uniform as possible. When the pattern of field variability is unidirectional, long and narrow blocks should be used. When the pattern of variability is not predictable, blocks should be as square or rectangular plots of double or multiple rows. These are preferably long, single row plots. While using single row plots, take into account how to correct variability arising from inter-plot competition or border effects due to neighboring plots within a block. If a single row plot is used, then guard rows of same variety should be planted to minimize the border effects. After the decision has been made to use an appropriate design for the trial, the treatments (elite clones and check varieties) have to be randomized properly. Use any statistical software for making randomization. For technical details in dealing with randomization of treatments refer to Gomez and Gomez (1984).

Trial Management

Follow standard agronomic practices and crop protection measures to raise a good yam crop (see Mignouna et al. 2009). The most common agronomic practices to be followed include:

- Depth/height of ridge or mound of at least 40 cm
- Planting spacing of 1 meter intra row (along ridges/mound = between stands) and 1 meter between ridges (inter row). This will result planting density of 10,000 stands per hectare.
- Planting depth of 15 to 20 cm to prevent setts from exposure to sun scorching and rodents
- **Weed control:** Variety trial plots should be kept free of weeds to ensure optimum crop growth and performance. Weed competition is a serious problem during early crop growth (planting to emergence) and this has to be controlled with the application of suitable herbicides. Apply a combination of diuron (a systemic pre-emergent) and glyphosate (a contact) herbicide for effective weed control. Mix diuron and glyphosate at 2.3 L and 1.8 L, respectively, per hectare rate. Application should be done not later than 7 days after planting (DAP) of the yam. Subsequent manual weeding at least twice should be applied to further control weeds in the trial plot.

- **Earthening-up or Remounding:** This activity is required to provide an optimum soil environment for proper development of the roots and tubers. It is normally done during weeding but when there is excessive root and tuber exposure as a result of heavy rains or rodents it has to be done separately using hoes.
- **Staking and Trailing:** Yam is a climber and may require proper staking depending on the agroecology for optimum crop growth and performance. The variety trial could be conducted with or without staking depending on the trial objective. If the trial is supposed to be staked, a proper trellising method should be applied to reduce the number of stakes required for the trial area. Staking is normally done about a month after planting when 90% of the sprouts would have emerged in a plot. Use bamboo sticks or other material locally available or PVS pipes of uniform height (2−3 meters). Regular guiding and training of the yam vines (particularly lateral branches) to the stake must be carried out at least twice a week for proper twining during the active growth of the plant.
- **Harvesting:** The yam variety trial could be harvested between 7 and 9 months after planting depending on the species and maturity duration. Likewise planting operation, maximum care, and precaution must be given during harvesting to avoid varietal mixture and for proper data collection. Before the harvesting operation, one has to prepare proper labels and arrange other items required for harvest operation. On harvesting day, the harvestable net plot is carefully marked and tubers dug out manually. All harvested tubers from the plot are packed on the harvested spot in each plot and prepared label tags for the corresponding plot assigned for collection of relevant harvest data and proper storage of tubers after data collection.

Environmental and site descriptors: Record the environmental and site specific parameters of the location where the trial is being conducted. These include longitude, latitude, altitude, soil, and climate data. Record the climate data (temperature, rainfall, humidity, etc) for the trial period and also information on soil physical and chemical properties that help to explain spatial patterns among experimental sites and agroecological zones. Data from environmental and site descriptors are important for the interpretation of the results of the trial.

Trial Information Sheet

SITE AND TRIAL INFORMATION			
1. Trial Identification Data:			
Trial code:			
Trial name:			
Year (Day-Month-Year)			
Country:			
Location:			
Agro-ecology:			
Altitude (masl)			
Latitude:			
Longitude:			
Responsible Institution		**Responsible person**	
Name:		Name:	
Address		Address	
Phone		Phone	
E-mail		E-mail	
2. Trial installation data			
Trial design:			
No. of entries			
No. of replicates			
No. plant per plot			
No. of rows per plot			
Plot size (m × m)			
Between plants distance (m)			
Between row distance (m)			
Planting density (plants/ha)			
Date of planting			
Date of harvesting			

SITE AND TRIAL INFORMATION			
3. Field data			
Predominant soil texture:			
Organic matter (%):			
Soil pH:			
Total Nitrogen (N):			
Phosphorous [P] (ppm)			
Potassium [K](ppm)			
Field history cropping season t-1			
Field history cropping season t-2			
Field history cropping season t-3			
4. Crop management data			
Fertilizer:			
Name	**Date of application**	**Content**	**Dose**
Weed control/hoeing			
Name of product (mechanical or chemical)	**Date of application**	**Content**	**Dose**
5. **Weather data (daily basis)**			
Record daily weather data on temperature (max, min, average), rainfall, relative humidity etc using Hobo Remote Monitoring System or nearest weather station using separate data sheet			

Evaluation Parameters 5

The evaluation parameters in variety trials usually encompass an array of plant traits/ characteristics that are either virtually independent of the environment or that are highly influenced by the environment. Traits virtually independent of the environment are descriptors recorded to ensure distinctness and uniformity of the variety whereas those influenced by environment are recorded to determine its value for cultivation and use in targeted environments. Yam variety trialling should consider recording the following array of parameters.

Period of Vegetative Development

1. Number of Tubers Planted [number] (NTP): Count of the tubers planted per plot.
2. Seed Setts (Tubers Planted) Weight [kg](SETW): Record Weight of all seed setts to be planted in a plot in kilograms.
3. Number of Emerged Sprouts/plot [number] (NEP): Count the emerged sprouts (plants) per plot every week starting from first sprout (plant) on hill emergence date
4. Days to First Sprout Emergence [date] (DAYFE): Count the number of days from planting to the first sprout in a plot emerged.
5. Days to 50% Emergence [date] (DAYSE): Count the number of days from planting to 50% of the sprouts in plot emerged.
6. Establishment Rate [percentage](STRATE): Record the proportion of established plants per plot from the number of seed setts planted at two months after planting. Take count of well-established plants in a plot and calculate the % of plant establishment as the number of established plant in a plot divided by the total number of seed setts planted in a plot multiplied by100.
7. Secondary Sprouting [scale](SECSP): Record emergence of a new secondary sprout from the planted seed tuber/sett in a plot at three months after planting using a binary scale 0 = absent , 1 = present.
8. Days to First Leaf Emergence [date] (DAYLE): Count number of days planting to the first leaf emergence in a sprouted shoot in a plot.
9. Sprout Length [cm] (SPLENG): Measure the length of sprout at 20 days after emergence. Average of at least five plants in a plot.

10. Sprout Color [scale] (SPCOLO): Score the predominant color of sprout (vine) in a plot at 20 days after emergence on 1 to 5 scale: 1 = Green; 2 = Purplish green; = Brownish green; 4 = Dark brown; 5 = Purple; 99 = Other (specify).
11. Hairs on Sprout [scale] (HAIRSP): Record absence or presence of hairs on a sprout (vine) at 20 days after emergence using a binary scale 0 = Absent; 1 = Present.
12. Spines on Sprout [scale] (SPNSP): Record absence or presence of spines on sprout/vine of young plants in a plot at 20 days after emergence using a binary scale 0 =Absent; 1 = Present.
13. Spine Base Color [scale] (SPBCOL): Record absence or presence of colored spot at spine base of a sprout at 20 days after emergence using a binary scale 0 = Absent; 1 = Present.
14. Date of 1st Flower Initiation [date] (DATFI): Record the date of first flower initiation in a plot or the date any of the plants in the plot shows the first flower.
15. Date of 50% Flowering [date] (DATF): Date of 50% of the plants in a plot are having at least one flower/inflorescence.
16. Flowering Degree/intensity [scale] (FLRI): Scoring when more than 50% of the plants in a plot have flowered as:

Scale	State	Description
0	No bud	No inflorescence and not flowering at all.
1	Aborted bud	Presence of small or rudimentary inflorescences/flowers that can show an abortion or abscission point at the joint of the pedicel.
3	Low	Flowering is scarce with the presence of few flowers (buds, flower buds, flowers, fruits,and flower abscissions) per inflorescence and per plant (**Less than 10 inflorescences per plant**)
5	Moderate	Flowering is moderate with some flowers (buds, flower buds, flowers, fruits) per inflorescence and per plant (**10−29 inflorescences per plant**)
7	Profuse	Profuse flowering with many more flowers (buds, flower buds, flowers, fruits) per inflorescence and per plant (**30−50 inflorescences per plant**).
9	Extremely profuse	Extremely profuse flowering with abundant flowers (buds, flower buds, flowers, fruits) per inflorescence and per plant (**More than 50 inflorescences per plant**).

17. Number of Female Flowers per Inflorescence [scale](NFFPI): Record the number of female flowers per inflorescence on average of 5 flowered plants in a plot as 1 ≤ 10, 2 =11−25; 3 = 26−100, 4 ≥101.
18. Days to End of Flowering [date] (DAYEF): Count the number of days from 50% sprout emergence to date when the plant does not produce new flowers in a plot.
19. Sex [scale](SEX): Score sex of plant in a plot as 0 = Not flowering (Unknown); 1 = Female, 2 = Male ; 3 = Female and male (predominantly female); 4 = Male and female (predominantly male).
20. Inflorescence Type [scale] (INFT): Score inflorescence type as 1 = Spike, 2 = Raceme; 3 = Panicle

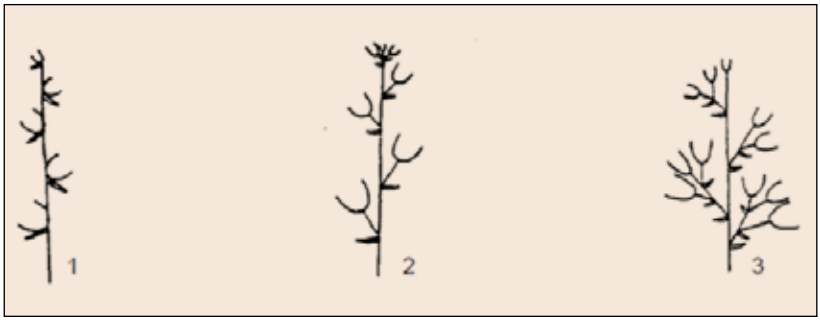

Figure 2. Inflorescence type (Source: IPGRI/IITA 1997).

21. Fruit Formation (female and monoecious genotypes only) [scale] (FRTF): Score fruit formation on female and monoecious genotypes in a plot as 0 = No fruit set; 1 = Yes.
22. Intensity of Fruit Set (female and monoecious genotypes only) [scale] (FRTINT): Score the intensity of fruit set when more than 50% of the plants in a plot are bear fruit as 1 = Low ; 2 = Medium; 3 = High.
23. Fruit Development (female and monoecious genotypes only) [scale] (FRTDEV): Record fruit development on female and monoecious genotypes in a plot as 1 = Mostly well developed, 2 = Mostly poorly developed.
24. Plant Vigor [scale] (PLNV): The capacity of vine and leaves of the new plant for survival or strong health growth and scored using a three category scale at two months after planting (a subjective

evaluation of all the plants in the plot, then the predominant vigor is recorded) as:

Scale	State	Description
1	Weak	75% of the plants or all the plants in a plot are small, few leaves and thin vine.
2	Medium	Intermediate or normal.
3	Vigorous	75% of the plants or all the plants in a plot are robust with thick vine and leaves very well developed or with abundant foliage.

25. Plant Type [scale] (PLNT): Assess plant type in a mature stem before senescence (5 to 6 months after emergence) and score as 1 = Dwarf; 2 = Shrub-like; 3 = Climbing.
26. Twining Habit [scale] (TWNH): Assessed on mature stem before senescence (5 to 6 months after emergence) as 0 = No; 1 =Yes.
27. Stem Number per Plant [number] (STNP): Count number of stems per plant at two and five months after emergence. Average of at least five plants in a plot.
28. Number of Internodes to First Branching [number] (NINFB): Count number of internodes to first branching (5 to 6 months after emergence). Average of at least five plants in a plot.
29. Stem Internode Length of Mature Plant [cm] (INODL): Record internode length of mature stem before senescence 1 m height in cm (5 to 6 months after emergence). Average of at least five plants in a plot.
30. Stem Diameter of Mature Plant [mm] (STDMP): Measure stem diameter of mature plant before senescence at 15 cm from the base of the plant (5 to 6 months after emergence). Average of at least five plants in a plot.
31. Spines on Stem Base [scale] (SPNSB): Record spines on stem base of mature plants (5 to 6 months after emergence) in a plot as 0 = Absent, 1 = Few ; 2 = Many

32. Spines on Stem Above Base [scale] (SPNAB): Record spines on stem above base of mature plant (5 to 6 months after emergence) in a plot as 0 = Absent, 1 = Few; 2 = Many.
33. Leaf Shape [scale](LFSHP): Record leaf shape of mature plants in a plot (5 to 6 months after emergence) as 1= Ovate, 3 = Cordate, 5 = Sagittate, 7 = Hastate.

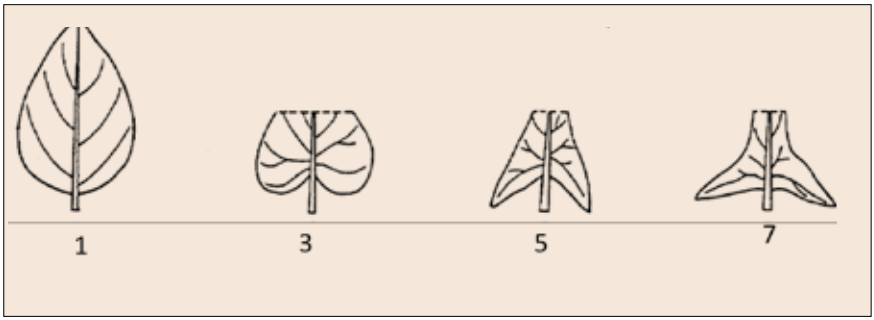

Figure 3. Leaf shape (Source: IPGRI/IITA 1997).

34. Leaf Apex Shape[scale](LFAPX): Record leaf apex shape of mature plants (5 to 6 months after emergence) as 1 = Obtuse, 2 = Acute, 3 =Emarginated

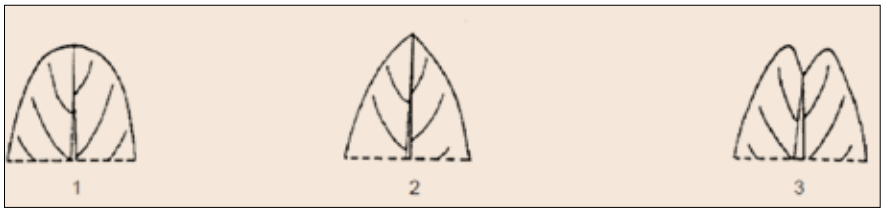

Figure 4. Leaf apex shape (Source: IPGRI/IITA 1997).

35. Date of 50% Senescence [date] (DATS): Date when 50% of the plants in a plot are showing signs of foliage senescence
36. Days to 100% senescence [days](DAYHS): Count the number of calendar days from date of 50% sprout emergence to date when 100% of the plants senesced in a plot.
37. Senescence Stage [scale] (SE): Score foliage senescence of the plants in a plot at 6 months after planting using a scale from 1 to 9.

Scale	State	Description
1	Very late	All the plants in a plot still show green foliage (green leaf and vine)
3	Late	75% of plants in a plot with still green foliage but few plants (up to 25% plants in a plot) showing up to 25% of leave senescence.
5	Medium	50% the plants are still green or on the onset of senescence. Only 50 % plants in a plot with 25% of the leaves showing senescence or slight yellowing.
7	Early	The plants have senescent foliage (75% of the plants in a plot with 50% leaves showing sign of yellowing but the vines still green).
9	Very early	The plants are completely senescent, yellowing is complete and uniform (both leaves and vine 100 % senescence)

39. Aerial Tuber (Vine Bulbil) Formation [scale] (BULBIL): Score presence of aerial tuber/bulbil as 0 = Absent; 1 = Present.
39. Total Aerial Tuber/Bulbil Number per Plant[count] (BULBPL): Count the number of aerial tubers on plants in a plot and record the average (total aerial tubers number divided by number of plants producing aerial tubers in a plot).
40. Aerial Tuber Shape[scale](BULBSP): Record aerial tuber shape as 1 = Round, 2 = Oval, 3 = Irregular (not uniform), 4 = Elongate

Period of Harvest

1. Number of Plants Harvested per Plot [number] (NPH): Count number of plants at harvest per effective plot.
2. Tuber Maturity [scale] (MTAE): Record maturing of tubers after emergence in months as 1 = up to 6 months, 2 = 7−8 months, 4 = 9−10 months.
3. Absence/Presence of Corms on Tuber [scale] (CORM): Score corm status of tubers as 0 = Absent; 1 = Present.
4. Corm Size [scale] (CORSZ): Record corm size in relation to tuber size as 1 = Small; 2 = Intermediate; 3 = Large

5. Corm Ability to be Separated from Tuber [scale] (CORSEP): Record the corm ability to be separated from the tuber using a binary scale 0 = No; 1 = Yes.
6. Corm Type [scale] (CORTYP): Record corm type as 1 = Regular ; 2 = Transversally elongated ; 3 = Branched
7. Number of Marketable (ware size) Tubers per Plot [number] (NMT): Count the number of tubers in a plot weighing 1 kg and above harvested per effective plot.
8. Number of Non-Marketable (under ware size) Tubers per Plot [number] (NNoMT): Count the number of tubers in a plot weighing less than 1 kg harvested per effective plot.
9. Number of Rotten or Diseased Tubers per plot [number] (NRDT): Count the number of rotten or diseased tubers harvested per effective plot.
10. Weight of Marketable (ware-size yam) Tubers per Plot [kg] (MTW): Weigh marketable (ware-size yam) tubers harvested per effective plot. The unit of measure is kilograms.
11. Weight of Non-marketable (under ware-sized yam) Tubers per Plot [kg] (NoMTW): Weigh non-marketable (under ware-sized yam) tubers harvested per effective plot. The unit of measure is kilograms.
12. Weight of Rotten or Diseased tubers per plot [kg] (RDTW): Weigh rotten or diseased tubers harvested per effective plot. The unit of measure is kilograms.
13. Tuber Shape [scale] (TBRS): Visual scoring of the predominant shape in the entire plot or family as a unit using a four categories scale: 1 = Spherical/round ; 2 = Oval; 3 = Cylindrical; 5 = Irregular.
14. Tuber Size [scale](TBRSZ): Visual score of the predominant size of tuber in the entire family or plot as 1 = Small (less than 15 cm length), 2 = Medium (between 15 and 25 cm length), 3 = Big (more than 25 cm length).
15. Tuber Surface Texture [scale] (TBRST): Scoring the texture of the tuber peel surface as 1 = Smooth; 2 = Rough.
16. Thorniness of Tuber [scale] (TBRT): Scoring the presence or absence of thorns on the tuber skin as 0 = Absent; 1 = Present.

17. Intensity of Thorns or Spines on Tuber Surface [scale](ITTS): Score the intensity or degree of thorns/spines on tuber surface as 0 = No; 3 = Few; 7 = Many.
18. Tuber Sprouting at Harvest [scale] (TBRSH): Score tuber sprouting at harvest as 0 = No; 1 = Yes.
19. Tendency of Tuber to Branch [scale] (TTB): Score the branching behavior of tubers as 0 = No branch; 3 = Slightly branched; 5 = Branched; 7 = Highly branched.
20. Position of Tuber Branching [scale] (PTB): Score the point/position of tuber branching as 1 = Upper third; 3 = Middle ; 5 = Lower thir.d
21. Marketable Tuber Length [cm)] (MTL): Record the marketable tuber length in cm. Average of 5 representative tubers per plot
22. Non-Marketable Tuber Length [cm)] (NMTL): Record the non-marketable tuber length in cm. Average of 5 representative tubers per plot or any available non-marketable tubers in a plot.
23. Marketable Tuber Length in Scale [scale)] (MTLS): Record the marketable tuber length in cm and report as 1 = small (< 20 cm); 2 = medium (21−40 cm; 3 = long (> 41 cm). Average of 5 representative tubers per plot.
24. Marketable Tuber Width [cm] (WMT): Measure the marketable tuber width in cm at the widest part. Average of 5 representative tubers per plot.
25. Non-Marketable Tuber Width [cm] (WNMT): Measure the non marketable tuber width in cm at the widest part. Average of 5 representative tubers per plot or any available non-marketable size tuber.
26. Roots on the Surface of Tuber [scale] (RTBS): Score the appearance of roots at surface to tuber as 0 = No roots; 2 = Few; 3= Many.
27. Place of Roots on the Tuber [scale] (PRTBS): Record the position of appearance of roots at surface to tubers as 1 = Lower; 2 = Middle; 3 = Upper; 4 = Entire tuber.
28. Cracks on the Tuber Surface [scale] (CTBRS): 0= Absent ; 1 = Few ; 3 = Many.
29. Crazy Roots on Tubers at Harvest [scale] (CRZROOT): Record appearance of crazy roots on tubers at harvest as 1 = Present; 2 = Absent.

30. Prickly Appearance of the Tubers [scale](PATBR): Record prickly appearance of tubers as 1 = No, 2 =Yes
31. Wrinkles on Tuber Surface [scale](WTS): Record wrinkles on tuber surface as 1 = Few, 2 = Many.
32. Tuber Skin Thickness [mm](TST): Record tuber skin thickness in mm. Average of five representative tubers per plot.
33. Tuber Skin Thickness Scale [scale](TSTS): Record tuber skin thickness in mm and record as 1 < 1mm, 2 ≥1mm. Average of five representative tubers per plot.
34. Tuber Flesh Color Upper Part [scale] (TBRFCU): Visual scoring of the flesh color at the upper part of the tuber at harvesting time using as: 1 = White; 2 = Creamy white; 3 = Yellow; 4 = Purplish; 5 = Purplish white; 6 = Creamy; 7 = Brownish white; 8 = Deep purple; 9 = Orange.
35. Tuber Flesh Color Middle Part [scale] (TBRFCM): Visual scoring of the flesh color at the middle part of the tuber at harvesting time using as: 1 = White; 2 = Creamy white; 3 = Yellow; 4 = Purplish; 5 = Purplish white; 6 = Creamy; 7 = Brownish white; 8 = Deep purple; 9 = Orange
36. Tuber Flesh Color Lower Part [scale] (TBRFCL): Visual scoring of the flesh color at the lower part of the tuber at harvesting time using as: 1 = White; 2 Creamy white; 3 = Yellow; 4 = Purplish; 5= Purplish white; 6 = Creamy; 7 = Brownish white; 8 = Deep purple; 9 = Orange
37. Tuber Flesh Color Reading (TFCR): Read tuber flesh color using color reader or standard color chart
38. Uniformity of Flesh Color in Cross-section (from cortex to center)[scale] (UTFC): Visual scoring as 0 = No, 1 = Yes.
39. Texture of Flesh [scale] (TXF): Record tuber flesh texture by feeling as 1 = Smooth, 2 = Grainy; 3 = Very grainy.
40. Time of Flesh Oxidation after Cutting [scale] (TFOXD): Score based on the time (in minutes) lasted for the flesh to become or not oxidized as 1 = < 1minute; 2 = 1−2minute; 3 = > minute.
41. Flesh Oxidation color [scale](FOXDC): Visual scoring as 1 = Grey, 2 = Purple, 3 = Orange 4 = Brown; 99 = (Other).
42. Intensity of Tuber Flesh Oxidization [scale] (INTOXD): Score intensity of tuber flesh oxidation at different time intervals (0, 30, 60 and 180 minutes after cutting) as 0= no oxidization; 1= slight oxidizing; 3= highly oxidizing

Disease Scoring

6

1. Yam Anthracnose Disease Incidence [Percentage] (YADI): Take anthracnose incidence recording twice: First inspection at 10 to 12 weeks post planting and second inspection after 2 to 4 weeks before harvesting. Take count of anthracnose “blight”/”leaf spot” affected plants and calculate the % of infected plants as number of infected plants in a plot divided by total number of plants in a plot times 100%.
2. Yam Anthracnose Disease Severity Score [scale] (YADS): Score anthracnose severity as 1 = no visible symptoms of anthracnose disease; 2 = few anthracnose spots or symptoms on 1 to ~25% of the plant; 3 = anthracnose symptoms covering ~26 to ~50% of the plant; 4 = symptom on > 51% of the plant; 5 = severe necrosis and death of the plant. Estimate mean anthracnose severity by summing severity scores > 1 in a plot divided by total number of symptomatic plants.

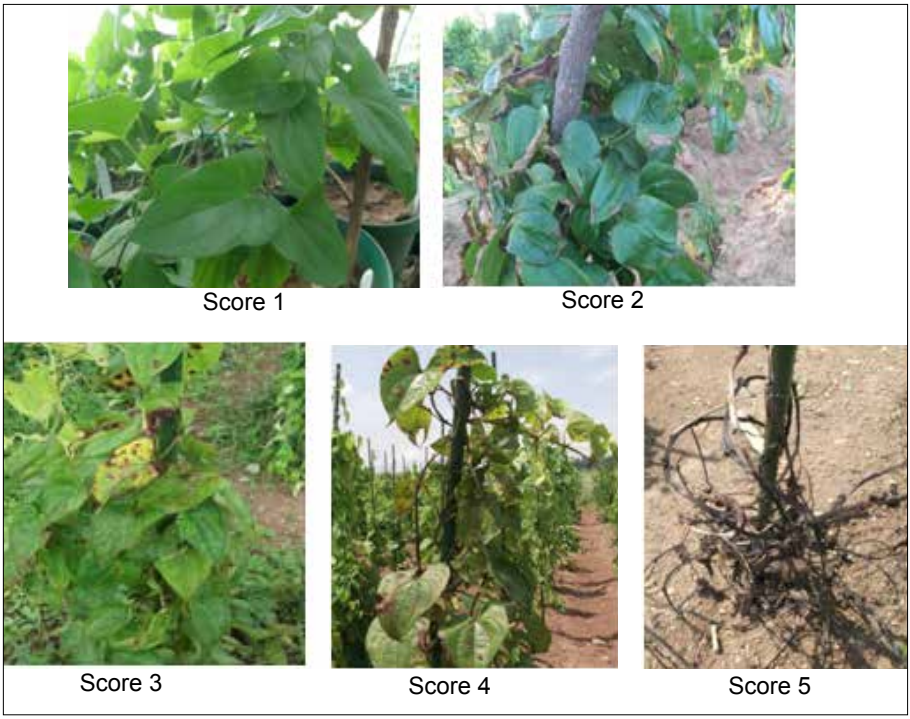

Figure 5. Visual scale for anthracnose scoring.
(Pictures from IITA Germplasm Health Unit).

3. **Virus Incidence [percentage] (VRSI):** Take virus incidence recording three times: the first inspection at 8 to 10 weeks post planting, the second inspection after 4 to 6 weeks after first inspection for virus symptoms, and the 3rd and final inspection 4 to 6 weeks after the second inspection for virus symptoms. Take count of virus disease affected plants and calculate the % of infected plants as number of infected plants in a plot divided by total number of plants in a plot times 100%.

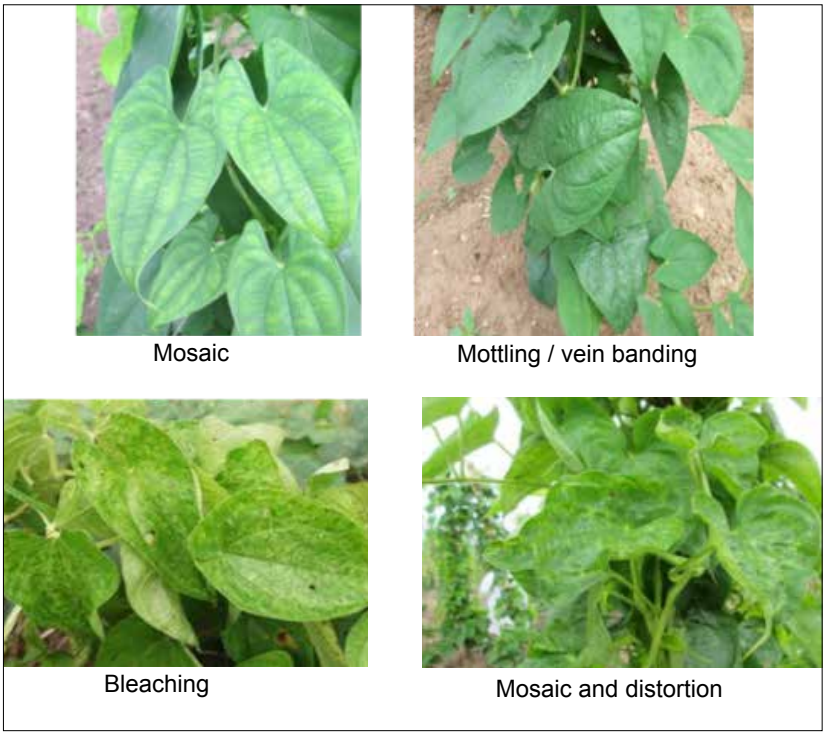

Figure 6. Virus symptoms. (Pictures from IITA Germplasm Health Unit).

4. Virus Severity Score[Scale] (VRSS): Score virus severity in 1-5 scale as below

Virus symptoms description on leaf/ whole plant	Symptom severity rating scale	Picture
No visible symptoms and virus negative	1	
Mosaic on most leaves; symptom recovery with time	2	
Mild symptoms on few leaves but no leaf distortion	3	
Severe mosaic on most leaves, leaf distortion	4	
Severe mosaic (bleaching), severe leaf distortion and stunting	5	

(Pictures from IITA Germplasm Health Unit).

This data should be taken three times during the virus incidence scoring and the mean of the three readings reported. This will enable study of the disease progression.

Estimate mean severity by summing severity scores of >1 in a plot divided by total number of symptomatic plants.

5. Dry Rot Score at harvest [scale] (DRYROT): Score nematode attack (dry rot) on tuber at harvest as 1 = Absent; 2 = Present.
6. Scale Insect on Tubers at Harvest [scale] (SITH): Score scale insect on tubers at harvest as 1 = Absent; 2 = Present.
7. Scale Insects on Tubers at Harvest [scale] (SIRH): Score scale insects on rhizomes at harvest as 1= Absent; 2 = Present.
8. Mealybugs at Harvest [scale] (MLYBH): Mealy bugs on tubers at harvest as 1 = Absent; 2 = Present.
9. Galls on Tubers at Harvest [scale] (GALTH): Galls on tubers at harvest as 1 = Absent; 2 = Present
10. Wet rot at Harvest [scale] (WTROTH): Wet rot on tubers at harvest as 1 = Absent; 2 = Present.

Quality Characteristics of Tubers

7

1. Ease of Peeling [scale] (ESPLG): Record ease of peeling to tubers as 1 = Difficult; 2 = Easy; 3 = Usually eaten unpeeled
2. Poundability of Boiled Tuber[scale](PBT) = Score poundability of boiled tubers as 1 = Poor; 2 = Good.
3. Cooking Time [min](COOKT): Record cooking time to softness in minutes.
4. Discoloration of Cooking Water [scale](DCW): Record discoloration of cooking water as 1 = Very low, 2 = Intermediate, 3 = Very high.
5. Appearance of Tuber after Cooking [scale] (ATAC): Record appearance of tuber after cooking as 1= Poor; 2= Fair; 3= Good.
6. Color of Tuber after Cooking [scale](CTAC): Record color of tuber after cooking as 1= White, not colored, 2 =Highly colored.
7. Attractiveness of Cooked Tubers [scale] (ACT): Record the attractiveness cooked tuber with respect to color alone as 1 = Low; 2 = Intermediate; 3 = High.
8. Texture of Cooked Tuber [scale](TCT): Record texture of cooked tuber as 1 = Smooth; 2 = Grainy; 3 = Fibrous.
9. Stickiness of Cooked Tuber[scale](SCT): Record the stickiness of cooked tuber as 1 = Sticky; 2 = Very sticky.
10. Taste of Cooked Tuber[scale](TAST): Record the taste of cooked tuber as 1 = Very Bitter, 2 = Bitter, 3 = Sweet, 4 = Very sweet.

Calculated Variables

Several variables can be derived from the raw data collected in yield trials. These include total tuber yield, marketable tuber yield, and average tuber weight among others.

Variable	Abbreviations	Unit	Formula
Percentage plants emerged	PPE	%	$PPE = (\frac{NPE}{NTP})100$
Percentage of plants harvested	PPH	%	$PPH = (\frac{NPH}{NTP})100$
Days to 50% flowering	DF	Days	DF = DATF-DATE
Days to Physiological Maturity	DM	Days	DM = DATS-DATE
Total number of tubers per plot	TNTP	Tubers/plot	TNTP=NMT+NNoMT + NRDT
Total number tuber per plant	TNTPL	Tubers/plant	$TNTP = \frac{TNTP}{NPH}$
Marketable tuber per plant	NMTPL	Tubers/plant	$NMTPL = \frac{NMT}{NPH}$
Total tuber weight per plot	TTWP	Kg/plot	TTWP = MTW+NoMTW +RDTW
Total tuber weight per plant	TTWPL	Kg/plant	$TTWPL = \frac{TTWP}{NPH}$
Marketable tuber weight per plant	MTWPL	Kg/plant	$MTWPL = \frac{MTW}{NPH}$
Total tuber yield no adjusted	TTYNA	t/ha	$TTYNA = \frac{TTWPL*PLD}{1000}$
Total tuber yield adjusted	TTYA	t/ha	$TTYA = (\frac{TTWP}{PLS}) * 10$
Marketable tuber yield no adjusted	MTYNA	t/ha	$MTYNA = \frac{MTWPL * PLD}{1000}$
Marketable tuber yield adjusted	MTYA	t/ha	$MTYA = (\frac{MTW}{PLS}) * 10$
Average tuber weight	ATW	g	$ATW = (\frac{TTWP}{TNTP}) * 1000$
Average marketable tuber weight	AMTW	g	$AMTW = (\frac{ATW}{NMT}) * 1000$
Average tuber length	ATL	cm	$ATL = (\frac{MTL + NMTL}{2})$
Average tuber width	ATWD	mm	$ATWD = (\frac{WMT + WNMT}{2})$

Where: PLS= Size of plot and **PLD**=Planting Density.

References 9

Gomez, K.A. and A.A.Gomez. 1984. Statistical procedures for agricultural research. 2nd Editon. John Wiley and Sons. 657 pp.

Hamadina, E.I. 2011. The control of yam tuber dormancy: a framework for manipulation. IITA, Ibadan, Nigeria. 60 pp.

IPGRI/IITA. 1997. Descriptors for yam (Dioscorea spp.). International Institute of Tropical Agriculture, Ibadan, Nigeria/International Plant Genetic Resources Institute, Rome, Italy.

Mignouna, H.D., M.M. Abang, R. Asiedu, and R. Geeta. 2009. Yam (Dioscorea) husbandry: Cultivating yams in the field or greenhouse. Cold Spring Harbor Protocls (this issue). doi: 10.1101/pdb.prot5324.

Yam field, Ibadan, Nigeria. Photo by IITA