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RESEARCH PAPER

# Overview of the importance of existing yam (*dioscorea species*) diversity in farmers' fields their implications for breeding programmes

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**Abstract**

**An overview of the importance of existing yam (Dioscorea species) diversity in farmers' fields their implications for breeding programmes was carried out with the aim to determine the importance of yam diversity for breeding objectives, what leads to losses of yam diversity across yam growing zones, an inventory of the cultivated Dioscorea spp in farmers' fields, understanding the reasons that underlie the cultivation of the different Dioscorea spp in the yam growing zones of the country, determine yam diversity variation across yam growing zones, identify farmers prioritize Dioscorea spp and preference trait(s) across yam growing zones, and documentary of the cultivated Dioscorea spp for each yam growing zones for national yam database. It was observed in the overview that Yams diversity is the bedrock of food sovereignty. Access to seed yams from yam diversity is common foundation of pests and diseases resistance which are the basis for the future food. It was also observed that high yield, good post-harvest storage capacity, good tuber surface characteristics, resistance to diseases, good culinary quality, adaptability to all type of soil, ease of harvest and early maturing are the most important criteria farmers (100%) in the yam growing zones look out for in selecting diverse yam species for planting in their farms. These traits could be used as criteria for the development of yam varieties by the yam breeding programmes. It was observed that diversity of species and diversity within species provide protection for crops against pests and diseases. The growing of just one uniform crop runs counter to this basic survival strategy and leaves crop plants exposed to diseases or pests, which can decimate an entire region's harvest. A case study is the Potato blight of 1845 in which Awake (2001) reported that one million Irish died and more than one million emigrated from Ireland to United States of America. Also Awake (1998) observed that as crop extinction is proceeding catastrophically fast, the loss of plant varieties can make crops increasingly vulnerable to failure.**

**Keywords: Dioscorea species, diversity, farmers' fields, preference criteria and yam zones**

## Introduction

Yam *species* is a staple food crop for over 300 million people in the tropics and subtropics (Mignouna *et al.,* 2003). Nigeria is one of the most important yam producing countries in the world and is the world leading producer of the world food yams and the world's largest consumer of yam (Ezulike *et al*, 2006). Nigeria contribution to the world production of yams is about 70%. The crop plays a key role in guaranteeing household food security and occupies 14.6% of the total cropped area of Nigeria as at 2009. The annual yam production is estimated to be 37 million metric tonnes in 2009 (FAOSTAT, 2009). Yam is an important food security crop for poor resource farmers. When it is planted, some varieties are harvested in piece meal by milking for home consumption and as such regarded as security crop (Nweke, 2016). The maturity period is between seven and nine months when compared with cassava, and cocoyam which take 9 to 12 months to mature (Onwueme, and Sinha, 1991). The yam tuber is prepared in several ways for eating. Yam can be boiled and eaten in some cases without salt or even eaten with Sauce. It could be fried, boiled and pounded into *fufu* or ground into flour for other uses such as in commercial value addition (used for bread making, biscuits, processed into starch, doughnuts, chinchin and other food products) to provide important energy. The yam tuber can be put to other uses such as a cash/export crop; livestock feed and has cultural values. It could be used in ceremonies such as marriages, funerals etc (Akintola, 2008). In the Southeastern part of Nigeria especially in the Iboland, the crop is reverenced and celebrated yearly as the king of all crops. This makes the crop an important crop. In yam growing states, the crop has been used for income generation and for home consumption (Nweke, 2016). As a result, many indigenous landraces of *Dioscorea speciesexists* (Teshome and Amenti 2010).

Among the *Dioscorea species, Dioscorea rotundata*(white fleshed yam*)*is estimated to account for 79% of the total world food yam production (IITA, 1995) and Nigeria is the largest world producer of yams producing 31.5 million tons annually (CBN, 2003). Most of the yam tubers are consumed locally. Due to increasing World population mainly in the developing countries of Africa, yam production is no longer meeting the aggregate demand. In order to meet annual demand, yam production must increase by 3-4%. At present, yam export is only marginal. Due to lack of officially released record, improved high yielding disease/pest resistant varieties of *Dioscorea spp* in commercial quantity have not been documented in farmers' fields (Nwankwo and Nwaigwe 2016). Yam species are diverse in nature. There are *Dioscorea rotundata (*white yam), *Dioscorea cayenensi*s (yellow yam), *Dioscorea alata* (water yam), *Dioscorea dumetorum* (trifoliate yam/three leafed yam), *Dioscorea bulbifera* (Aerial yam) and *Dioscorea esculenta* (Chinese yam). These six species are cultivated in West Africa as food yams. As in the case of natural yam diversity, Spore (2016) reported that seed keepers, food producers, scientists as well as scholars all over the world are dedicated to renewing a food system that is better aligned with ecological processes that has crop diversity. Alternatives to industrial agriculture that decrease seed diversity worldwide should be reconsidered and agro-ecology that reclaims traditional methods that work to secure a healthier diverse future maintained. It was noted that since green revolution, ecological science has taught mankind the value of crop diversity to ensure sustainability, an increase in food production and resilience. At the ecological level, agro-ecology and biodiversity-based organic farming rejuvenate natural crop diversity on which sustainable food security depends. Biodiversity and soil rich in organic matter are the best strategy for climate resilience and climate adaptation.

Biodiversity is more than the diversity of yam genetic resources. This is because biodiversity includes the knowledge that led to the development and for its use. This knowledge is embedded in a dynamic web of relations between human beings and nature, continuously responding to new problems and finding new solutions. However, environments rich in yam diversity are ecologically resilient to climate change and other threats. Yam diversity are beneficial to people and the environments. Some yam diversity has varieties with improved water and nutrient use efficiency, canopy cover that led to less soil erosion and smothering weeds, increased soil and environmental biodiversity as a result of more insect pollinators leading to more diversity in the yam plants.

Most countries consider some yam species as of minor importance mainly because its use as a food has decreased considerably. Farmers in most West African countries also indicate that many yam cultivars have disappeared because the crop's use as a food has led to the loss of valuable yam species (Mcharo *et al*., 2001). The emphasis placed on the use of early maturing yam cultivars to fit into the crop rotation systems of modern agriculture has also certainly caused genetic erosion of very late maturing yam varieties with many desirable attributes (Msemo, .2003). In countries where yam breeding programs exist, new bred varieties have replaced many native yam cultivars which they claimed are low yielding. The knowledge of yam diversity is important in yam breeding and yam development. It is important to conserve yam diversity by including them in the farming menu in order to have better understanding and reliable information about the diversity of *Dioscorea species* in the country (CIP, (2000). Furthermore, due to the constant change in climate and environment, and new pests and pathogens, new genes are required by plant breeders for crop variety improvement (Gibson, *et al.,* 2008). These new genes can always come from yam diversity. Conservation of this yam diversity can ensure food security, especially to resource- poor farmers who cannot afford the improved yam varieties. Conservation and preservation strategies of this yam diversity need to be strengthened to avoid genetic erosion of the yam diversity and as Abidin, et al., (2005) acknowledged, the new genes required for breeding may be found in this yam diversity.

It has been found that the yam diversity used by farmers exhibited high morphological variability (Agbo, and Ene, (1994). Conservation of yam diversity is important for improving food security and nutrition for the present and future human population especially for the resource poor farmers dealing in subsistence farming (Agbo. and Ene, 1994). High yam diversity ensures adequate food supply and traits to improve yield, quality, resistance to pests and diseases and adaptation to changing environmental conditions. Gibson, *et al* (2008) mentioned that *Dioscorea spp* are adapted to their local areas and have developed resistance to pests and diseases; this has made them gain recognition from the resource - poor farmers. However, in most cases this yam diversity produces low yields that lower the yam production (Freyre, *et al,* 1991)). However, yam diversity is a good source of carbohydrates, proteins, fiber, iron and moderately rich in vitamin C (Woolfe, 1992) which poor resource farmers have been used to sustain life.

Diversity in *Dioscorea spp* is assessed by measuring variation in phenotypic traits such as diversity in colour, shape of the leave and growth habit (Agbo. and Ene, 1994). Kays, (1985) reported that phenotypic traits have led to domestication of useful plants landraces. According to Cervantes-Flores, *et al* (2011), it was observed that increased subsistence production of yam crops by farmers is by the use of yam diversity. This has the potential to improve the food security of poor households in both rural and in urban areas and by reducing dependence on purchasing food from abroad. Use of yam diversity had been encouraging farmers to pursue sustainable intensification of production through the use of improved inputs (Nwankwo. and Opara, 2015). This will require a dramatic increase in the use of fertilizer, organic inputs, improved tillage systems, irrigation and conservation investments, combined with the development of well-functioning input and output markets to help farmers acquire and use improved inputs, and market their (surplus) output and reduce transaction costs and risks. Increased productivity will reduce pressure on marginal lands, as the intensification of cultivated land with *Dioscorea spp* will reduce pressure to crop in fragile marginal lands.

Poor households make use of diversity in *Dioscorea spp* to access their food from subsistence production. Subsistence/smallholder agriculture can play an important role in reducing the vulnerability of rural and urban food-insecure households, improving livelihoods, and helping to mitigate high food price inflation through the cultivation of different *Dioscorea spp*. There is a need to significantly increase the productivity of subsistence/smallholder agriculture and ensure long-term food security by cleaning up these *Dioscorea spp* for food production ( Mcharo, *et al.,* 2001).

The purpose of this overview was to:

1. determine the importance of yam diversity for breeding programme
2. determine what leads to losses of yam diversity across yam growing zones
3. have an inventory of the cultivated *Dioscorea spps* in farmers' fields
4. understand the reasons that underlie the cultivation of the different *Dioscorea spp* in the yam growing zones of the country.
5. determine yam diversity variation across yam growing zones
6. identify farmers prioritize *Dioscorea spp* and preference trait(s) criteria across yam growing zones and
7. document the cultivated *Dioscorea spp* for each yam growing zones for national yam database.

**What is yam diversity?**

Clement *et al* (2011) defined crop diversity as the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Sharma (1980) indicated that yam diversity may include chance seedlings which have been selected and cultivated by farmers for millennium of years. Major driving forces for crop diversification include: Increasing income on small farm holdings, withstanding price fluctuation, mitigating effects of increasing climate variability, balancing food demand, improving fodder for livestock animals, conservation of natural resources, minimizing environmental pollution, reducing dependence on off-farm inputs, depending on crop rotation, decreasing insect pests, diseases and weed problems, and increasing community food security. Therefore, the introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses.

The yam crop is rich in diversification. For instance, there are 600 species of yams in the family *Dioscoreaceae* (Daisy, 2000). This indicates the existence of great diversity of this crop which can be utilized for needed improvement (Okoli, 1984). In Nigeria, there are different species such as white yam (*Dioscorea rotundata),* yellow yam (*Dioscorea cayenensis*) and water yam (*Dioscorea alata)*. There are also Trifoliate yam (*Dioscorea dumetorum*), Aerial yam (*Dioscorea bulbifera*), and Chinese yam (*Dioscorea esculenta*). There are numerous wild species such as *D*. praehensilis. As there is diversity between species, there is also diversity within species. For example, in the species *Dioscorea rotundata* alone, there are more than 1000 varieties of white yams. Therefore, the relative importance of this species determined the extent of their usage resulting in loss of some varieties over time. Farmers cultivate very diverse mixtures of hundreds or even thousands or more of different varieties/population of yams and allow them to evolve and adapt to their local conditions. These evolutionary populations are living gene banks in the farmers own fields. The genetic diversity present in the yam population of *Dioscoreaceae* is not deliberately created by man but it is naturally present and therefore referred to as landraces (Teshome and Amenti 2010).

**The importance of yam diversity**

Yam diversity could make significant contribution in the diet of the people or as varieties in the farming system of the people or as progenitors in breeding programme for the farmer preferred traits. Although most of these chance seedlings in the yam diversity have not been scientifically evaluated and released as varieties. In yam growing States of Nigeria, yam farmers depend on the yam diversity for survival. The diverse yam landraces are adapted to their local areas and have developed resistance to local pests and diseases. The diverse yam landraces gained recognition from farmers as result of their good qualities and as such could be used for genetic recombination (Nwankwo, *et al.*, 2012).

Some of these diverse yams have superior agronomic characteristics which could qualify them for official recommendation and registration as varieties. The diverse yams also contain valuable sources of resistance to important diseases and pests, capable of adaptation to environments where yam is grown, and other desirable characteristics such as high dry matter content which is associated with culinary qualities preferred by consumers (Huamán, *et al*., 1999). Huaman, *et al.,* (1999) also pointed out that this yam diversity could be a source of resistance or immunity to yam virus disease (YMV) which has been a hindrance to yam cultivation. These desirable qualities of diverse *Dioscorea spp* could qualify them for official release by national varietal release committees for commercial yam production and for export. According to Singh (2016), the procedure for clonal selection of landraces is identical to that for pure line selection and superior performing clones evaluated in replicated yield trials are released as variety.

The diversity that exists in the yam crop could be conserve for future usage. The yam diversity could be evaluated to identify those resistant to pests and diseases of ecological origin and to select them in terms of high yield and adaptability to different environmental conditions by breeding programmes. The yam diversity could be built up and reserve as breeding materials of native species that have nutritional and industrial potential for crop improvement programme, and to register as what farmers can use to generate income through commercialization and export.

Yam diversity is an essential pillar of peasant farmers' strategies for survival and autonomy through reducing costs and risks. In the agro ecological production system, the peasant farmers have cultivated, sustained and developed millions of diverse varieties of yam crops over millennia throughout the world especially in the yam growing belts of the world. These have nurtured the healthy population of pollinators and pest predators.

Yam diversity is essential for improve health of the people as a result of diverse yam plants with increased micronutrient contents such as vitamin A, iron, ascobic acid and other minerals and vitamins in the edible tubers. Yam diversity has led to increased sharing of knowledge through exchange within and between small scale producers, countries and peasant farmers. Yam diversity enhanced the freedom for peasant farmers to choose the agrarian system and culture that value it in a holistic sense in the face of economic values imposed by a free market which destroy yams in cultural freedoms.

Yam diversity is an essential part of life that resulted from a collective work of thousands of generations of farmers since ancient times. These farmers generated vast diverse of yams that are in different rainbow of colours, shapes and flavours so it could be deliver to future generations of farmers. For Africa yam, both indigenous and Asian yams have been the foundation of their culture and yam production system.

**Methods for the introduction of yam diversity**

***New and improved yam species:*** New and improved yam species can be introduced by the farmers though two different ways: Farmers have received new and improved yam species for experimentation in their farms over centuries. These have escaped the farmer’s field either through theft or by act of good will into other farmer’s hands. This has summed up to many existing yam varieties with wide variation in their abilities to adapt to climatic conditions.

In plant breeding the aim is to produce new, improved yam varieties/cultivars and to release or produce genetic variation in the characters (or traits) in which there was an interest. Once such variation is released it is necessary to identify and then select the desired types – those that have a better expression of a particular character or combination of characters are readily accepted and adopted. Once identified the selected types need to be stabilized and multiplied for use and exploitation.

***Introduction of new yam species:*** Farmers have introduced new yam crop species to diversify the yam crop production systems using available irrigation system, rainfall and soil fertility, to have access to technologies such as yam minisett seed technology, vine cuttings, fertilizer, water, marketing, storage and processing. New yam species have been introduced as a result of .household related factors such as food self-sufficiency requirement as well as investment capacity or as result of market related factors including output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly. Yam crop species have been included in the farming systems of the people as a result of Institutional and infrastructure factors such as farm size and land tenancy arrangements, research, extension and marketing systems and government regulatory policies like yams for exports.

***Breeding new and improved crop varieties:*** Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stresses, water salinity, water stress, high vigour to overcome weeds and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change. Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health (Clement et al., 2011).

***Classical Breeding of variation:*** Conventionally this is achieved through sexual crossing, of cultivated lines. Two parents with expression of desirable characters between them are intercrossed and the progenies with the desired characters in new combinations are selected. This process relies on the segregation of alleles at all the relevant genetic loci, during the normal process of meiosis. At fertilization there is a random fusion of gametes to give the embryo which develops into the seed. The offspring that develop contain novel combinations of the alleles that were originally dispersed between the two parents.

***Mutation:*** Natural and artificial mutation promotes evolution in plants. Mutation can be on the morphological or physiological traits, and its effect could be visible to the naked eye and therefore could be measurable. Mutation may affect plant parts or a whole plant. Mutation although when artificially applied, its effect cannot be predicted on the plant character. Its application is liken to an accidental discharge in the chromosomes. Its impact could be beneficial or not. Artificial mutation when induced by chemicals, X-rays, irradiations could lead to chromosomal aberration and the re-arrangement of the genetic constitution of the organism results into a new individual yam plant with desirable or undesirable traits due to the alteration of the genes. The genetic aberration may result to dwarfness or tallness in plants, erect leaf or dropping leaf, early or late maturing crop, disease resistance or even susceptible to diseases. Mutation could even lead to better taste, improved quality such as high protein, good quality starch, appreciable skin surface texture and others. Appropriate screening scales are employed to identify them. These traits could be agriculturally useful and can be useful to the farmer, industrialists, and horticulturalists and even to the plant breeder. Many mutations are visible and are expressed in the phenotype and can be expressed in the phenotype and can be measured. Mutant genes have been of great importance in providing clues in the way in which genes act to produce a given phenotype. All these form up the diverse yam crop.

**Sustainability of yam diversity**

The peasant farmers using peasant systems for rediscovering, conserving and exchange seed yams with local adaptation due to local selection and reproduction in farmers' fields. To maintain and increase the genetic diversity that underlies the world food systems, this will enable the yam farmers to have the capacity and flexibility to address diverse environments, a changing climate and hunger in the world. The yam farmers should continue with the production practices of agro ecology such as intercropping, manuring, and integrating crops, compost and local seed based ecological principles. When local markets support yam diversity, it enables peasant producers to sell a wider range of cultivated diverse yam crops conserved locally.

Yams diversity is the bedrock of food sovereignty. Access to seed yams from yam diversity is common foundation of pests and diseases resistance. They are the basis for the future food. They shape at each cycle the type of food people eat, how it should be grown and who grows it. Seed yams from yams diversity are the vessel that carries the past, the accumulated vision and knowledge, and practices of peasant yam farmers and farming communities worldwide. Yam diversity maintains the people's farming systems.

**Inventory of yam diversity in farmers' fields across yam growing zones**

An inventory of yam diversity was conducted in farmers' fields across the yam growing zones of the country in 2016. The study areas included: Benue and Nassarawa in North central States of the country. Ebonyi and Enugu States in the Southeastern States of the country and Oyo and Ogun in the Southwestern part of the country. Yam production is very important in these states. The states were chosen in order to obtain as much yam diversity as possible.

To assess the diversity of yams at each location, a Participatory Rural Appraisal approach was used to obtain relevant information from the farmers. The approaches used included focus group discussions with yam farmers and key informant interviews. In each of the zones, a group of at least 30 yam farmers were organized and taken through a farmer's cultivated yam field. The information obtained was organized in a form that can be well communicated.

Table 1 indicated that 65.6% of the yam fields visited showed that *D. rotundata* are however cultivated sole by many farmers and in larger hectares from the selected States in yam growing zones. The cultivation of *D. rotundata* in large areas was attributed to the flesh colour of the yam which is white. This flesh colour attracts the eye and led to the versatility of *D. rotundata* in the food menu and in the industry as raw material for flour and Starch. The tuber has good storability. Farmers rely on *D. rotundata* for both home consumption and marketing for income. Another reason adduced for large hectare of cultivation was that *D. rotundata* matures earlier, taking 6 to 7 months to mature than other *Diocorea species*. As such it is easier to use *D. rotundata* for fast income generation when compare to other species.

*D. cayenensis (yellow yam)*, on the other hand was observed on 11.0% of farmers' fields in the study area. The farmers cultivate white yams and yellow yams separately in the same field. However, no field of sole *D. cayenensis* was observed. This was attributed to the high cost of its seed yam. Even though it is the yam that attracts high price. Its small hectare of cultivation means that it is often consumed very quickly after harvesting. This yam species take up to 9 months to mature. Certain varieties of the yellow yam stay up to 2 to 3 years in the soil before harvesting. The yield is very high compare to single year harvest. These are called the giant yellow yam (Ogbodo). The late maturity of yellow yam discourages farmers from cultivating it in large hectares. The seed yam is also not available making it very expensive and increasingly difficult and out of reach for the resource-poor farmers. The flesh colour which is yellow is attractive and is richer in food nutrients than *D. rotundata.* Its yellow flesh colour is an indication of containing elevated amount of vitamin A than *D. rotundata*. It has low glycemic index.

*D. dumetorum,* accounted for 0.01%and *D. bulbifera* 0.006% in farmers' fields visited. This indicated that very few farmers cultivated these *Dioscorea Species* on small hectares. These diverse yam Species were planted separately in the same field with *D. rotundata*. This low hectare of cultivation was attributed to the relative low market value of these varieties compared with *D. rotundata*, for instance. This situation places these varieties in danger of extinction if no serious measures are taken to collect and conserve them. Flesh colours of some *D. dumetorum* and D. *bulbifera* varieties are yellow in colour, an indication of elevated nutritive quality than *D. rotundata*. However, *D. dumetorum* and D*. bulbifera* are late maturing. In an ideal condition, they may take up to 8 to 10 months to mature.

In the yam growing states, *Dioscorea alata* are cultivated in 21.7% farmers' fields on large hectares but not as sole crop*.* It is being planted separately in the same field with *D. rotundata.* Although the flesh colour is white/cream, it contain more water and less sugar than *D. rotundata.* It has high survivability in areas where *D. rotundata* fails*.* It is crop of high vigour. This attribute made it to be popular to be cultivated in poor soils more than other yam species.

In the Southeastern part of the country-Nigeria, *Doscorea esculenta* and *Dioscorea bulbifera* are also in danger of extinction, due to the low number of farmers cultivating it and in small hectares. Although *Dioscorea bulbifera* are always planted in mix cropping with *Dioscorea. rotundata* or close to trees. Its flesh colour is yellow and rich in vitamin A. It is not a popular yam in many yam growing areas of Nigeria.

In many States and among the selected yam farmers, there was no one found cultivating Chinese yam (*Dioscorea esculenta*), which may mean that the variety has gone extinction or at the brink of extinction*.* This yam species is multiple tubering which in many cases are small. The white flesh colour is sugary. Both the feeder roots and the vines contained spines. These attributes coupled with its low market value might have contributed to many of the farmers lack of interest in the cultivation of this species of yam.

**Table 1:** Number of farmers with different yams species in their field in the selected states of yam production zones in Nigeria

| **State** | **Number of farmers Sole white yam *(D. rotundata***) | **No. of farmers that cultivated sole yellow yam *(D. cayenensis*)** | **No. of farmers that cultivated sole water yam (*D. alata)*** | **No. of farmers that cultivated sole Trifoliate yam *(D. dumetorum*)** | **No. of farmers that cultivated sole aerial yam (*D. bulbifera*)** | **No. of farmers that cultivated sole chiness yam (*D. esculenta*)** | **No. of farmers that cultivated White yam + yellow yam** | **No. of farmers that cultivated White yam + water yam** | **No. of farmers that cultivated White yam + trifoliate yam** | **No. of farmers that cultivated White yam + aerial yam** | **Mixture of all yams in the same field** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ebonyi | 17 | - | - | -- | - | - | 7 | 4 | 1 | 1 | - |
| Enugu | 21 | - | - | - | - | - | 3 | 5 | 1 | - | - |
| Benue | 22 | - | - | - | - | - | 2 | 6 | - | - | - |
| Nasarawa | 19 | - | - | - | - | - | 4 | 7 | - | - | - |
| Oyo | 21 | - | - | - | - | - | 2 | 7 | - | - | - |
| Osun | 18 | - | - | - | - | - | 2 | 10 | - | - | - |
| Total | 118 | - | - | - | - | - | 20 | 39 | 2 | 1 | - |

**The prioritize *dioscorea species* in the selected yam growing zones**

The prioritize *Dioscorea species* that are found in farmers' fields across the selected yam growing zones are presented in Table 2. These varieties of white yam (*Dioscorea rotundata)* are mainly found in the field of farmers. These white yam varieties are cultivated as diversified intra-specific *Dioscorea rotundata.* Reasons for the preferred white yam varieties are given in Table 3. However, the cultivated varieties of white yams preferred in the different yam growing zones are presented in Table 2.

**Table 2:** Prioritize *Dioscorea species* across the selected yam growing zones

| Yam zones | Cultivar | Yam zones | |
|---|---|---|---|
| BENUE | Kokoro | NASARAWA | Ogoja |
| | Amola | | Danacha |
| | Lasiri | | Gbango |
| | Ogoja | | Sampaper |
| | Ame | | Gisa |
| | Miyango | | Ame |
| | Hebalo | | Dorban |
| | | | |
| ENUGU | Ekpe | OSUN | Yandu |
| | Adaka | | Okoiyawo |
| | Obiaoturgo | | Gbangu |
| | Okpani | | |
| | Alumaco | | |
| | Agbaocha | | |
| | Abii | | |
| | | | |
| EBONYI | Ekpe | Oyo | Yandu |
| | Adaka | | Okoiyawo |
| | Obiaoturgo | | Kemi |
| | Nwopoko | | |
| | Jiaga | | |
| | Agbaocha | | |
| | Abii | | |

**Source:** Field Survey, 2016

**Preference criteria for the cultivation of diverse yams in farmers' fields**

Morpho-agronomic traits: In a survey conducted among yam farmers in yam growing areas in Nigeria in 2016 in which six states namely: Benue, Nasarawa, Enugu, Ebonyi, Oyo and Osun were involved. The preference morpho-agronomic criteria for selecting diverse *Dioscorea Spp* for cultivating in the field by farmers are presented in Table 3. Thirty farmers from each location were asked why they choose to plant diverse *Dioscorea spp* either sole or close by in the same field. The number of farmers were pooled and converted to percentages. Their responses are presented in Table 3.

**Table 3:** Preference morpho-agronomic traits for selecting *Dioscorea Spp* in the selected localities for cultivation

| Traits | Ebonyi | Enugu | Benue | Nasarawa | Oyo | Osun | Total | % |
|---|---|---|---|---|---|---|---|---|
| High yield | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| High Seed yam production | 9 | 2 | 7 | 1 | 3 | 5 | 27 | 15.0 |
| Good post harvest storage capacity | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Smooth tuber surface characteristics | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Resistance to pests | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Resistance to diseases | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Flesh colour characteristics | 25 | 28 | 15 | 22 | 17 | 23 | 130 | 72.2 |
| Good culinary quality | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| No staking requirement | 21 | 17 | 18 | 19 | 20 | 12 | 107 | 59.4 |
| Ease of harvest | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Thick skin | 11 | 19 | 18 | 21 | 23 | 24 | 116 | 64.4 |
| Early maturing | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Late maturing | 3 | 5 | 7 | 4 | 2 | 1 | 22 | 12.2 |
| Profuse branching of the tuber | 2 | 2 | 3 | 4 | 2 | 4 | 17 | 9.4 |
| Low lateral vines | 2 | 4 | 5 | 2 | 1 | 3 | 17 | 9.4 |
| Profuse thorniness of the tuber | 2 | 3 | 4 | 2 | 4 | 3 | 18 | 10.0 |
| Sparse thorns' | 1 | 4 | 4 | 2 | 5 | 2 | 18 | 10.0 |
| Presence of red spots in the tuber flesh | 1 | 1 | 2 | 1 | 2 | 4 | 11 | 6.1 |
| Hairiness of tuber surface | 1 | 2 | 1 | 0 | 1 | 1 | 6 | 3.3 |
| Spines on tuber surface | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1.1 |
| High vigour | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Multipletuber production | 20 | 16 | 15 | 5 | 12 | 10 | 78 | 43.3 |
| Low seed tuber production capacity | 29 | 28 | 28 | 19 | 24 | 28 | 156 | 86.7 |
| High staking demand | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Poor post -harvest characteristics of ware tubers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Early bulking | 30 | 28 | 29 | 27 | 29 | 30 | 173 | 96.1 |
| Deeper tubering | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Shallow tubering cc | 23 | 30 | 29 | 28 | 25 | 30 | 165 | 91.7 |

**Source:** Field Survey, 2016

Table 3 above showed that the following traits: high yield, good post harvest storage capacity, smooth tuber surface characteristics, resistance to pests and diseases, good culinary quality, ease of harvest, high vigour and early maturing are the most important criteria 100% of the farmers in the study areas look out for in selecting diverse yam species for planting in their farms. The good storability of these diverse yams enables the farmers to rely on them for both home consumption and income generation from sales in the markets. For other prominent criteria 59.4 - 96.7% of the farmers in the study areas selected diverse yam for cultivation based on flesh colour characteristics of the diverse yam species, little or no staking requirement of the different yam species, low seed tuber production capacity, early bulking, shallow tubering and thick skin of the diverse yam species. However, 1.1 - 43.3% of the yam farmers did not pay much attention on the following criteria in selecting diverse yam for planting in their farms: high number of seed yam production, Profuse branching of the tuber, late maturing, Low lateral vines production, profuse thorniness of the tuber, Sparse thorns, Presence of red spots in the tuber flesh,' hairiness of tuber surface, Spines on tuber surface Spines on vine surface, multiple tuber production, high staking demand, poor post-harvest storage characteristic of ware tubers and deeper tuber bulking in the soil. They felt that these criteria were not contributing to the economic production of the yams. For example, Yam species that produces high number of seed yams need not be planted since what are required for commerce are ware yam tubers for high income generation and yams that matures late delays high rate yam cultivation turnover and low income generation. The inclusion of these yam species into the farming systems is only an insurance measure against failure. Nevertheless, this farming system method promotes the conservation of yam diversity.

Environmental (biotic and abiotic) factors: The Environmental (biotic and abiotic) factors for selection and planting of diverse *Dioscorea Species* by farmers in the study areas are presented in Table 4.

**Table 4:** Environmental (biotic and abiotic) factors for selection of *Dioscorea Spp* by farmers in the study areas

| Environmental criteria for *Dioscorea Species* selection | Ebonyi | Enugu | Benue | Nasarawa | Oyo | Osun | Total | % |
|---|---|---|---|---|---|---|---|---|
| Poor adaptation to climate change | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Susceptibility to poor soils | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Soil selectivity | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Susceptibility to pests and diseases | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |
| Tolerance to acidic soils | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Tolerance to poor soils | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Tolerance to weeds | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Tolerance to drought | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Tolerance to high soil moisture | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Adaptability to all types of soils | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |
| Resistance to pests and diseases | 30 | 30 | 30 | 30 | 30 | 30 | 180 | 100.0 |

**Source:** Field Survey, 2016

Table 4 indicated the environmental factors that led to the selection of diverse *Dioscorea spp* for planting by various yam farmers in the yam growing areas. Prominent among the reasons the farmers (100.0%) for planting different yam species in the field are that most of the *Discorea species* are tolerant to acidic soils, tolerant to poor soils, tolerant to weeds competition, tolerant to drought, tolerant to high soil moisture, adaptable to all types of soils and, resistance to pests and diseases. The planting by mixing of the different varieties of the same species in the same field and planting of different *Dioscorea spp* close to other species in the same field is insurance against crop failures as a result of extremes of biotic and abiotic factors. This is only a good idea for subsistence farmers. Crop morphology may run counter against farm mechanization.

However, from the farmers' perspective, *Dioscorea spp* that did not meet the criteria acceptable by the farmers will be stepped down and this may lead to genetic erosion. Nevertheless, the traits preferred by farmers could be used as criteria for the development of yam varieties by the yam breeding programmes.

**Aim of yam diversity**

The aim of yam diversification is to increase yam crop organization so that farmers are not dependent on a single yam crop to generate their livelihood and income. When farmers only cultivate single yam crop, they are exposed to high risks of unforeseen climate events that could severely impact their production, such as emergence of pests and the sudden onset of drought. Introducing a greater range of yam varieties leads to diversification of yam production which can increase natural biodiversity and strengthening the ability of the yam crop to respond to these stresses, thereby reducing the risk of total crop failure and providing alternative means of generating income. With a diversified yamplot, the farmer increases the chance of dealing with the uncertainty that might be created by climate change. This is because different yam crops will respond to climate scenarios in different ways.

The process of farmer experimentation and the subsequent introduction of adapted and accepted varieties can potentially strengthen farmers' cropping systems by increasing yields, improving drought resilience, boosting resistance to pests and diseases and also by capturing new market opportunities. Research organizations are increasingly recognizing the potential contributions of yam diversity and the need to identify crops and varieties that are suited to a multitude of environments and farmer preferences. They are now better informed about the traits that should be incorporated in improved varieties, and to experiment with different crop varieties and management practices. Yam crop diversification provides better conditions for food security and enables farmers to grow surplus yamfor sale at market and thus obtain increased income to meet other needs related to household well-being. Yam crop diversification can enable farmers to gain access to national and international markets with new value addition to yam products, food and medicinal yam plants. Diversifying yam crop from the traditional one crop system can have important nutritional benefits for farmers and farmers can become more self-reliant in terms of food production. Diversification can manage price risk, on the assumption that not all yam crops will suffer low market prices at the same time.

Nevertheless yam diversity is essential for life. This was because of what happened in the 1840s. According to Awake (2001), in the 1840's, Ireland's population exceeded eight million, making it the most densely populated country in Europe. Potatoes were its dietary mainstay, and a single variety called lumpers was the most widely grown. In 1845, the farmers planted their lumpers as usual, but blight struck and wiped out almost the entire crop. Most of the Irish survived that difficult year. The devastation came the next year. Farmers had no choice but to plant the same potatoes again. They had no other varieties. The blight struck again, this time with overwhelming force. The suffering was indescribable. It was estimated that up to one million people died of starvation, while another 1.5 million emigrated, most to the United States. Those remaining suffered from crushing poverty.

In the Andes of South America, farmers grew many varieties of potatoes, and only a few were affected by blight. Hence, there was no epidemic. Clearly, diversity of species and diversity within species provide protection. The growing of just one uniform crop runs counter to this basic survival strategy and leaves plants exposed to disease or pests, which can decimate an entire region's harvest. That is why many farmers depend so heavily on the frequent use of pesticides, herbicides, and fungicides, even though such chemicals are often environmentally hazardous.

Usually response to economic pressures forces farmers to replace their many folk varieties with one uniform crop. Planting uniform crops promises for ease of harvesting, attractiveness of the product, resistance to spoilage, and high productivity. These trends began in earnest in the 1960's with what came to be called the green revolution. It does not promise protection from outbreak of pests and diseases.

**The peril of yam diversity**

Yam diversity last long in the yam fields of farmers who value yam diversity. As the industrial model of production, consumption and urbanization increases, rural societies are destroyed alongside with the yam diversity for food and their agrarian methods. Today's world uses genetically uniform monoculture of crops while destroying diversity. The wide spread of mining industries, petroleum exploration, construction of large dams and rapid urban development grab large land area under yam diversity cultivation. Intensive use of herbicides, pesticides and chemical fertilizers reduce the ecosystem function and unhealthy for yam diversity. Climate change put new pressure on yam diversity as new pests and diseases proliferate. Researching and breeding new varieties for industrial system de-value and erode yam diversity and indigenous knowledge that promote yam diversity. Government policies on the type of food to produce and industrial seed systems which jeopardize the freedom of peasant farmers' continuous maintenance of yam diversity. The uses of new crop varieties destroy yam diversity and farmers livelihoods.

Farmer experimentation using only native yam variety can limit the range of benefits and responses that may be found amongst the materials being tested, although local adaptation and acceptance are ensured. Introduced yam species could introduce new pests or turn to be weeds. Crop diversification leads to the difficulty for farmers to achieve a high yield in terms of tons per hectare since they have a greater range of crops to manage. In terms of commercial farming, access to national and international markets may be difficult to attend as a result of low yield, low price and, infrastructure for storage and transportation, Farmers may face risk from poor economic returns if the yam crops are not selected based on market assessment and not in sufficient demand. It may take a number of years to create a new variety with improved features and an additional number of years for it to be introduced into the market and adopted by farmers.

Before yam crop diversification selection is implemented, an inventory of yam varieties currently used by farmers should be compiled, as well as anew yam varieties not yet available to farmers for testing to know the strengths and weaknesses of current agricultural and seed systems and an in-depth understanding of the root causes any current and potential stresses. A decision to introduce new yam varieties needs to be founded on sufficient evidence that new yam varieties offer promising opportunities, and, equally, that their introduction will not expose farmers to increased risk. It is also important to monitor and evaluate (with farmer participation) the performance of new varieties, report results of performance and recommend next steps and changes to improve processes. It is also important to provide detailed information on yields and production conditions. In making decisions about diversification, farmers need to consider whether income generated by new Farm enterprises will be greater than the existing activities, Yam crop diversification may not be suitable for many farmers in terms of their land, labour, capital resources and markets for the yam crop species may be lacking.

The main barrier to introducing new and improved crop varieties through farmer experimentation is the misconception that local species have low productivity. This have been the major barrier for cultivating local yam species and this has resulted in the lost of yam diversity and ancient knowledge about resistant species. Other barrier to diversification is market demand which can lead farmers to produce fewer yam crops and to rely on chemical inputs. In turn, this can increase vulnerability of the agricultural system to external factors such as climate change and price fluctuations as well as loss of yam diversity.

For instance, Awake (2001) reported that between the years 1804 and 1905, there were 7,098 varieties of apples grown in the United States. Today 6,121 of those apples exist while —86 percent—are extinct. Pears have fared similarly. About 88 percent of the 2,683 varieties once grown are now extinct. And when it comes to vegetables, the numbers are even grimmer. Crop diversity is disappearing, the rich variety of types found within species. Diversity within the various kinds of vegetables grown in the United States has been slashed by 97 percent in less than 80 years. Additionally, Awake (1998) observed that 95 percent of the cabbage, 91 percent of the field maize, 94 percent of the pea, and 81 percent of the tomato varieties apparently no longer exist. This has been attributed to the spread of modern commercial agriculture and the subsequent demise of the small family farm, which has resulted in the loss of traditional, highly variable varieties of crops. The same result applied to *Dioscorea spp*.

More than 85% of yam diversity has been lost from commercial production. Of the 750 white yam varieties used in peasant food web in 1950, only about 255 varieties still exist. Most of the varieties in their local niches have gone extinction. They are existing in the memories of farmers who are now well advanced in age. This loss of yam diversity was attributed to wars and local clashes, continuous depleting soil fertility, pests and diseases influence, climate change, inability of the yam crops to adapt to modern agro-chemicals, impatient of farmers to continue to cultivate low yielding varieties and the advent introduction/release of high yielding varieties by national breeding programmes to replace low yielding existing yam diversity. The forgoing notwithstanding, the agricultural model imposed by agribusiness corporations, supported by international financial capital, and based on monocultures, the massive use of pesticides and the expulsion of peasant farmers who maintain crop biodiversity from the countryside to give way for infra-structural development, is primarily responsible for the loss of yam diversity. Therefore, this rich diversity within the *Dioscorea spp* has been genetically eroded especially within the *Dioscorea rotundata*.

The loss of plant varieties can make crops increasingly vulnerable to failure. For example, consider as mentioned earlier the Ireland's great potato famine of 1845-49, during which some 1000,000 people died of starvation when a plant disease wiped out most of the potato crop as a result of Genetic uniformity. Crop diversity is essential to life on earth. It is just as vital to the plants we grow for food as it is to those growing wild in the forests, jungles, and grasslands of the world. Diversity within a species matters. The numerous strains of yam, for instance, increase the probability that some strains will have the means to resist common plagues. The extinction of plants can affect food crops in at least two ways: first, by wiping out the wild relatives of cultivated crops, a potential source of genes for future breeding, and second, by reducing the number of strains within cultivated species. As crop extinction is proceeding catastrophically fast, various countries have responded to such concerns by setting up seed banks as insurance against the loss of important plants. Some botanical gardens have taken up the mission of species preservation. Science has supplied the powerful new tools of genetic engineering to increase species diversification.

To complement the effort of Science, over 1,000 gene banks were built worldwide during the 1970's and 1980's to amass and preserve plant genetic resources. But a number of these gene banks are deteriorating rapidly, and some of them have already closed. Reportedly, only about 30 countries now have facilities suitable for secure long-term storage and conservation of plant seeds. Crop diversity conservation should be everybody's concern. That is where the future food comes to the dining Table.

## Conclusion

A wide diversity of yams exists and especially in the study area, however more and more of this yam diversity is getting extinct. There is the urgent need to collect and conserve these species for breeding objectives. The maturity period such as, being early maturing for *Dioscorea rotundata* unlike *Dioscorea alata, Dioscorea cayenensis, Dioscorea dumetorum* and *Dioscorea bulbifera* which were late maturing and flesh colour are traits that were prominent criteria for planting them in the field. Income and food security were also major intensity of cultivation of a particular variety/species across all selected locations. Factors such as good culinary characteristics, high yield; good storage characteristic and resistance to biotic and abiotic stresses were traits that are of important criteria for selection of variety/species for cultivation.

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