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Historical trend in the development of yam research in Nigeria from 1923 to 2017- A Review

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Abstract

The development in Yam research in Nigeria has been of gradual process. The crop being African, did not receive attention in research early. The white man did not do much to assist Africans to work on their crop. As a result, lack of technology and scientific know-how delayed research in African yams from 1923 to early 1963. From 1963 to early 1970's, researches in yams were based only on evaluation of the yam crops' nutrient requirement and multiplication of the seed yam. In the late 1970 to 1983, there was the understanding of the floral biology and sexual behaviour of this Africa yam. Many Scientists who endorsed that the crop cannot be genetically improved started making a comeback. In the year 2001, the first hybrid yam genotypes was released by the collaborative effort of International Institute of Tropical Agriculture (IITA) located at Ibadan and National Root Crops Research Institute, Umudike, Nigeria which has the national mandate to research on yam. Since 2001 to 2016, 22 hybrid yam genotypes and five clonal white yam landraces have been officially registered and released as varieties. The conglomerate yields of these hybrid yam genotypes and the registered white yam clones in 2016 combined to make Nigeria the World's largest producer and consumer of yam. Much have been done from the 1990 to 2017 to develop and broaden the genetic base of Africa yam through conventional breeding, enhancing its multiplication ratio through vine cuttings and Aeroponics systems, cleaning of the seed tubers to obtain disease free planting material using tissue culture techniques, bioreactors and virus indexing, agronomic packages such as fertilizer rate and weeding regimes, however, much effort has not been put forth to help Africa yams through biotechnological approach. Despite the dazzling improvement in research already made, much is still needed to make this crop Nigeria's most prestigious carbohydrate food.

Introduction

Yams belong to a member of the family *Dioscoreaceae* which is made up of 600 species. Of the 600 species, only six genera are food yams (Onwueme and Sinha, 1999) Yam is an African crop. Some researchers in yam systematic have even gone a step further to pinpoint the Niger-Benue trough of Nigeria as the centre of domestication for the white guinea yam (Hahn *et al*, 1987). The yam plant is a monocotyledonous and annual herbaceous plant. It has long climbing stems which wind themselves around supports. A single plant produces between one and five tubers of varying shapes, each may weigh 1.5 to 7kg (Ukpabi and Okoli, 2002). Certain species produce *dioscorine,* a toxic alkaloid that is destroyed by cooking. Rich in starch and protein, yam is very popular tropical food. It grows in light, well drained soils and often the most fertile land is set aside for yam cultivation. The white guinea yam (*Dioscorea rotundata Poir)*and the yellow yam (*Dioscorea cayenesis*) originated in West Africa. *Dioscorea rotundata* has a white tuber flesh characteristic and is grown on a greater hectarage and produced on larger quantities than any other kind of yam in the world (Onwueme and Sinha, 1999). The leaves are heart shaped with pointed tips and spiny stem (in some varieties) which is circular in cross-section.

The West African country- Nigeria produces yam in vast quantity and is accounting for about 70% of the world's total yam production, and because of this, it is termed the largest producers of yams globally, followed by Côte d'Ivoire and Ghana respectively (need a reference). The yams are the most important staple food crops in West Africa (Ekpe *et al*, 2005) except for cereals (Onwueme and Sinha (1999). They also form an important staple food source in tropical countries including East Africa, the Caribbean, South America and Southeast Asia, however, West Africa remains the most important yam producing region of the World (Okonkwo, 1985). Yam is very significant in the past and in modern rural economies, and visitors to parts of the forest zone in the 1850's observed that yams there were one of the chief articles of food, "the staff of life" and the staple food of the population, the same today. In the transitional zone between the forest and savanna, yams and maize formed the staple food of the population (Agboola, 1979). Of the 600 known species of yams, only six are food yams. Out of these, the most popular, white yams, *Dioscorea rotundata* originated in West Africa which accounts for 90 percent of world production of about 25 million metric tonnes. Nigeria alone produces 70% of the world white yam output. The yam zone of West Africa is restricted peripherally to the forest and savanna areas of Nigeria, Ghana, and Cote d'voire, Cameroon, Benin and Togo. (IITA, 2008, FAO, 1998). Among the cultivated species of yam, white guinea yam (*Dioscorea rotundata* Poir) and yellow yam (*Dioscorea cayenensis*) are considered to be indigenous to West Africa (Degrass, 1993).

In traditional yam growing areas, the sets of seed yam are planted in mounds especially made at the end of the rainy season before the soil becomes too hard to work. The yams are planted during the dry season and begin to sprout at the onset of the next rainy season, during which tubers are gradually formed. Stakes are usually provided for the yam vine to climb on; either cut sticks or dried maize and guinea corn stems that have been left in the field for that purpose. Harvesting of the tubers starts in the middle or later part of the rainy season. In northern parts of Nigeria where yam growing is relatively new, the planting is usually done on ridges, and staking is extremely rare (Akintola, 2008).

The yam tuber is prepared in several ways for eating .It could be eaten boiled, roasted, fried, mashed or pounded 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).Farmers of old prided themselves in the number of yam tubers in their barns. It was traditionally a demonstration of the success of a farmer. The advent of new yams is a reminder of traditional festivities. In some parts of the Ibo land in southeastern Nigeria, yam is a male symbol. Women are not allowed to work anywhere in yam farms until the yam is ready for harvest. To the people, yam is the king of all food crops. In Ghana, yam is prepared to welcome important visitors while in Nigeria pounded yam is a national dish and a prestigious carbohydrate. The tuber is the main part of the yam plant which has high carbohydrate content (low in fat and protein) and provides a good source of energy.It can be consumed as boiled yam (the back which is usually peeled off contains vitamin C). Used as *fufu* when cooked and pounded, or fried in oil and then consumed. It is also processed into flour for use in the preparation of the paste. It consists of sapogenin and saponin alkaloids which are good at stimulating the heart because of its medicinal effect. It is also used as an industrial starch.Yam is also used in numerous events such as traditional marriages and occasions and as a staple food and in the production of flour and others

The economic importance of the yam plant is due largely to the tuberous underground stem, which is the tuber). Between 3.5 and 5 million hectares of land are put to yams cultivation annually with the bulk of production in the Southern parts and North Central of the country (International Institute of Tropical Agriculture, 2014). *Dioscorea rotundata* alone is estimated to account for 79% of the total world food yam production (International Institute of Tropical Agriculture, 1995) and Nigeria is the largest world producer of white yam (31.5 million tonnes annually (CBN, 2003) about 70% of the world food yams and consumer of yam (Ezulike *et al*, 2006). 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%. by 1995, yam production was only marginal due to lack of improved and high yielding disease/pest resistant varieties (International Institute of Tropical Agriculture , 1995), high cost of planting materials, storage losses from infection, low multiplication ratio, high manual labour requirement for weeding, staking and harvesting.

Future increases in yam output will have to rely on higher yield from improved varieties and constraints to production have to be tackled (Manyong *etal*, 2001). Since tubers could be eaten boiled, roasted, fried, mashed or pounded to provide important energy, variability in *D. rotundata* is almost the only avenue through which local farmers and consumers can obtain yams of their desired traits. Difficulty in inter- and intra-species hybridization in yam through conventional breeding is a limitation in yam improvement studies (Okoli *et al*, 1986, Timothy and Bassey, 2009). Over the years, producers have faced a number of difficulties, partly due to growing demand and more intensive production/farming methods. Declining soil fertility, an increase in disease linked to crop intensification and the high cost of seed- which accounts for 30 to 50% of production outlay- have created major obstacles to its development. As a result, yam had been the focus of a number of research projects (Spore, 2011).

Origin and distribution of yam: Yams are distributed throughout the tropics. A few yams are found in the warm regions of temperate zones (Mahungu and Otiende, 2004). Mahungu and Otiende (2004) observed that yams are mainly grown and consumed in three continents namely Africa, Asia and South America. In South America, it is common in the North Eastern parts of Brazil. Yams are also grown in the Caribbean and the South Pacific. Statistics, however, show that more yams are grown and consumed in West Africa than in any other part of the world.

The economic importance of yam plant: The economic important part of the yam plant is the tuber which is a modified stem structure that develops underground as a consequence of swelling in the sub apical part of a stolon and the subsequent accumulation of reserve materials (Benjamin and Mariano, 2007). The uses of yams include the following: Yam is a source of food. It is a staple food in many African, Caribbean and Pacific countries. The crop is an excellent source of energy. Many households generate high percent of their agricultural income from yam sales. In fact, yam cultivation and yam sales are sources of employer of labour and foreign exchange earner. Yam tuber could be put into industrial uses such as starch flour, feed for livestock and even dried yam vines could be used as mulch and manure in the farms. Yam is a major source of calories in Nigeria. The crop is also a good source of protein in the diet being the third after maize and rice. The crop plays important role as a ceremonies and social rites and in fact the crop can be a formidable force in the war against poverty and hunger if research and development measures are implemented to develop and disseminate technologies that can bring the crop into central focus in national food policies (Mignouna et al., 2014; Maroya et al., 2014).

Yam growing States in Nigeria: Yam is also widely grown in the humid tropical environment and is another major staple food in Nigeria and tropical African countries. In Nigeria, yams are produced in almost all the states of the Federation both in subsistence and commercial agricultural systems. They are of 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*). Yams are mostly grown in Benue that is why Benue State is mostly known as the food basket of the nation. Other states includes; Cross River, Adamawa, Delta, Ekiti, Imo, Abia, Edo, Kaduna, Ogun, Kwara, Ondo, Osun, Plateau and Oyo. Other areas of yam cultivation include: Ebonyi State, Enugu State, Nasarawa State and Delta State. All the States collectively put together led to Nigeria producing the vast quantity of yam which account for about 70% of the world's total yam production, and because of this, it is the termed the largest producers of yams globally followed by Côte d'Ivoire and Ghana respectively.

These species of yam in Nigeria grow better in some areas than others which are attributed mostly to the soil type. Before planting seed yam, the farmland is first cleared and ploughed. After harvest, yam tubers required for planting are set aside to stay for about 100 - 120days and the cut seed yams treated with wood ash which acts as a fungicide to protect them from rot or decay.

Yams yield formation depends upon a number of morphological, physiological and environmental characteristics. The yield of yam is a function of plant number per unit land area multiplied by storage tuber number per plant multiplied by average storage tuber weight. Tuber number and average weight are determined in sequence by various physiological events. Changes in one yield component as a result of environment will often lead to subsequent adjustments by the plant in yield components. With the initiation of tubers, their potential maximum number is determined first, next cell division and expansion determines the size of the tuber; finally, the synthesis of starch granules determines the density of starch in the cells (Hahn and Hozyo, 1984). Yield potential of tubers essentially depends on the potential production of total dry matter, and the proportion of dry matter diverted to the tubers. The leaves are considered as the source for dry matter production through photosynthesis, and the tuber as the sink for dry matter deposition.

Yam planting tends to be rigorous which includes tuber cuttings (Preparation of Setts), soil preparation as mentioned earlier (Mulching, the ridges, weed control), planting and care. Yam basically undergoes two phases namely growth and dormant phases. The growth phase occurs for about six to ten months depending on the species and then slowed down for two to four months, the slowing down process is called the dormant phases, these phases occur in the wet and dry season respectively.

Yam cultivation in Nigeria: Yam cultivation in Nigeria had been centered on the landraces which was developed through chance seedlings although have not been scientifically evaluated and release as variety but have been selected by farmers over many years of continuous cultivation (Nwankwo et al., 2017). These landraces have made significant contribution in the diet of the people as varieties in the farming system of the people for the farmer preferred traits. The genetic variability present in the yam landraces are not deliberately created by man but it is naturally present and therefore referred to as landraces (Teshome and Amenti 2010). In yam growing States of Nigeria, yam farmers depend on the landraces for survival. Some varieties of yam plant are harvested in piece meal by milking for home consumption and as such is regarded as security food crop (Nweke, 2016). The maturity period is shorter (between seven and nine months) compared to cassava, and cocoyam which take 9 to 12 months to mature (Onwueme, and Sinha, 1991). Landraces are well adapted to their local areas and have developed resistance to local pests and diseases. Landraces are able to gain this 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 landraces have superior agronomic characteristics which could qualify them for official recommendation and registration as varieties. The landraces 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 landraces could be included in breeding programmes as source of resistance or immunity to yam virus disease (YMV) which has been a hindrance to yam cultivation.

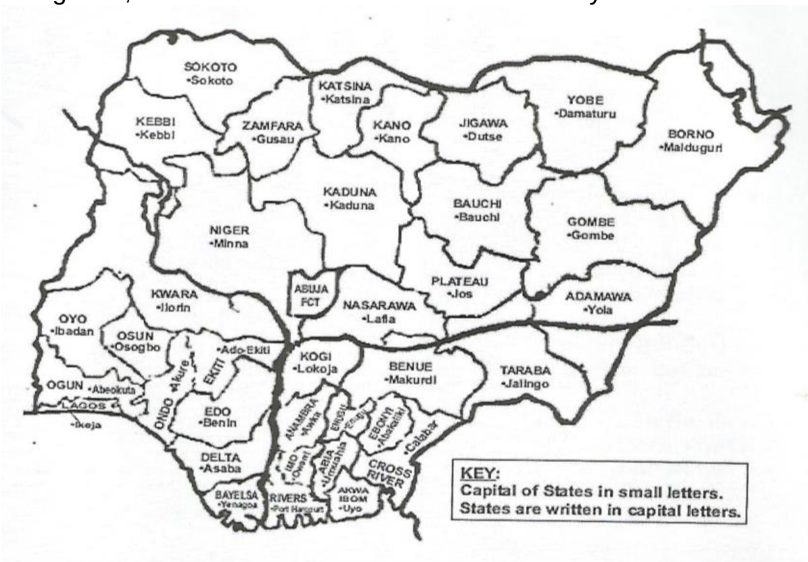

Fig. 1: Map showing locations of Yam producing States of Nigeria
Source: Ugo, (2000)

Since diversities also exist in yam landraces, they can be conserved for future usage. Some of these landraces are worth mention since they could be used for commercial production and export. The white yam landraces are: Obiaoturugo, Nwopoko, Alumaco, Ekpe, Adaka, Amola, Faketsa, Hembakwasi, Aloshi, Giwa, Yandu, Ame, paper, Awada, Hebalo and others. Some of the yellow yam landraces are: Ji-oku, Akupe- Ibeku, Oku-isi-ukwu, Giant yellow yam (Ogbodo) and others. Water yam landraces are: Sakata, Gborogboro, Um680 and others. Some of the three leaf yams are: Una-okposi, ofu-anya, Una- Nkporo, Una-asaga, Una-Nwonyeukwu, Una-aro, Una-oji-obi and others.

Due to increasing world population mainly in the developing countries in Africa, yam production is no longer meeting the aggregate demand. In order to meet annual demand, yam production must be increased by 3-4%. At present, yam exporting is only marginal due to lack of officially released, high yielding disease/pest resistant varieties of *Dioscorea rotundata* (Nwankwo and Nwaigwe 2016).Yam production have been stressed on agronomical practices, however, a research study carried out on the economic efficiency of this crop grown in some yam producing States with small farm holdings, which is labour-intensive, reveals that land, labour and material (fertilizers and chemicals), credit and extension services have a significant bearing on the yield of yam.

Trend in yam production in Nigeria: Prior to the oil boom in the early 1970s Degras (2000), observed that yam production increased by about 70% from 1960 to 1970 due to increase in area under cultivation and the yield level as a result of using improved varieties and production packages. In 1997, the world yam production was about 30 million tonnes (FAO, 1997), in which approximately 90% was produced in the yam belt of west and central Africa. The production trends indicated that world yam production has grown at 2.5% per year during 1965 and 1974 and 1.9% per year from 1975 to 1985 (Gebresmeskel and Oyewole, 1987). According to FAO statistics, the growth rate jumped to 10% per year in between 1985 and 1990. This was as a result of the combined effort of increases in yield at the rate of 4% per year and increases in area under cultivation by 6% per year. In West Africa, the corresponding annual growth rate were 5% for the yield and 7% for the area cultivated (Manyong *et al.,* 2001). The leading yam producing country in the world - Nigeria accounted for 75% of world production in 1997 and is experiencing an annual growth rate of as high as 6% for the yield and 10% for the area under cultivation the same period.

Ugwu *et al.,* (1996) and Manyong, (1996) noted that more than 70% of yam growing areas were found in the savanna region. This is because the savanna areas are better suited to yam production than the forest zone based on climate, soil, and pests and diseases concentration. Yam production in Nigeria in 1997 was about 23.3 million tonnes which was 70.7% of the world population (FAO, 1997). Despite that, the yield in farmers' field was relatively low compared with that from other West African countries. The high production of yam in Nigeria could be attributed to area under cultivation and not the unit yield per plant. For example average yield of 9. 6t/ha is obtained in Nigeria, while 10.83t/ha is obtained in Cote d' Ivoire, 10.94t/ha in Benin and 12.74t/ha in Ghana. Yam growth rate for 2011 in Nigeria stood at 5.4, but reduced to 4.9 in 2012 (Central Bank Nigeria, 2012), higher yields however continued. In 2014, Nigeria produced over 45.004 million metric tonnes of yam (FAO, 2014). This could be attributed to the combined research efforts of the National Root Crops Research Institute, Umudike and IITA, Ibadan in yam development.

Challenges in yam production: Bassey and Nwankwo (2017) reported that the major challenges in yam production can be categorized into ten groups namely: weed pressure, decline in soil fertility, soil borne pests and diseases, leaf disease, storage pests and diseases, Others are: labour cost for land (heap) preparation, harvesting, barn making, and lack of staking materials. Other hindrances to yam production include: deficiency in yam mechanization, use of traditional technology for production of seed yam, scarcity of planting materials (Manyong *et al*., 2011; Nweke *et al*., 1991) as well as consumer preference (Katung *et al*., 2006). Throughout the history of yam development, these have been challenges facing yam production. Only very few of these problems has research been able to give minimal solution.

Majority of the farmers keep about 25% of the harvested yam as planting material for the next season, however, when the quantity of seed yams required for planting is large, as result of expansion in farm size, the proportion as planting materials may be consistently higher (Katung *et al.,* 2006). As a result, the cost of planting materials has been shown to represent about 50% of the cost of yam production (Nweke *et al*., 1991). The traditional methods of yam production include double harvesting and cutting large tubers into sets of 150-1000g. The minsett technique using 25-50g sets to produce seed yam has been introduced to farmers but the rate of adoption is generally low (11TA, 1985). Using the vine cutting for seed yam production (Cabanillas and Martins, 1987) may not be practicable at the farmers' level because of rooting problems and extended growing period (Aighewi *et al.,* 2001).

Field pests and diseases, and storage pests and diseases constitute the most important problem in yam production. Pests such as yam beetles make holes in the tubers and reduced the quality of the tubers and also facilitate fungal infection leading to tuber rots. Attack by nematodes affects the quality of tubers too. An infestation by nematodes in yam producing areas increases due to the shortening of fallow period from seven to one year (Manyong and Oyewole, 1997).

It is also estimated that staking could double cost of yam production especially in areas where live stakes or crop stakes are not present in the farm for trailing of the vines. Stakes also deteriorate in value within a year demanding for fresh stakes in subsequent cropping year(s) and this poses a serious stress on the farmer who desires for high yield of the crop (Manyong *et al*., 2001). It is worrisome that this particular farm input is not considered within the confine of government input support. However, this problem could be tackled when the research results on non-stake yam is available which would be released to farmers in Nigeria.

Weeding is also considered as a major challenge to yam in the tropics. This is because weeds easily developed under stake condition because of low canopy cover (Manyong and Oyewole, 2001). The yam varieties in famers' field are no longer the heavy foliage type yet high yielding compared with older varieties and local types and this situation creates favorable condition and open spaces for rapid weed growth. As a result, farmers carry out three weddings before final harvest and this increases the overhead cost of production and reduces profit margins of yam farmers (Manyong and Oyewole, 1997). The use of pre- emergence herbicides such as primextra at 3kg ai per hectare or fluometuron +metolachor at 2-3+2-3kg ai per hectare recommended for effective weed control, (Katung *et al*. (2006) is not realizable as a result of lack of these weed control chemicals in the markets.

Yam development through genetic improvement in Nigeria

The International Institute of Tropical Agriculture (IITA) has a global mandate for research on yams within the Consultative Group on International Agricultural Research (CGIAR). The Institute's yam researchers develop and disseminate improved technologies targeted at increased productivity of yam-based systems in partnership with national programs and advanced laboratories. However, Yam is an African crop. The Whiteman left Africans to develop their crop and as a result genetic improvement of the yam crop took a very long time to start unlike crops like rice, wheat, barley and other cereal crops. Genetic improvement in roots and tuber crops such as cassava, potato and sweet potato began earlier than in the yam crop. For instance cassava breeding began in 1891 at the East Africa Agricultural and Forestry Research Station in Amani in Tanzania. Starting from 1923 to early 1970's, yam improvement was mainly on clonal evaluation of the crops' agronomic requirements. The genetic improvement of the crop was at zero level. In fact, it was said that yam cannot be genetically improved and as such many Scientist dropped pursuing their course of study on the crop. However, Scientists probe further to observe the genetic diversity which exists among economically important yam species. The two indigenous African yam species *Dioscorea rotundata* and *Dioscorea cayenensis* are still very diverse, as a result of local adaptation to ecological niches and, more important, because of consumer preferences for different types, and the wide spread association of yams with cultural and ritual practices (Eastwood and Steele, 1978). However, this variation and the likelihood of maintaining genetic diversity is now threatened by certain factors, such as; the use of preferred cultivars, increased cultivation of less labour–requiring crops such as cassava, maize and rice, and cultivation and adoption of other yam species like *Dioscorea alata* which are more tolerant to diseases and pests (Ngeve,1999). Since it was discovered that the crop is differentiated into male and female types, there must be a way of breeding the crop to produce superior progenies that would take over from the parents in terms of yield and resistance to pests and diseases ravaging the crops.

Closer observation indicated that the Crop *Dioscorea rotundata* is predominantly *dioecious* with plants bearing either all pistillate (female) or all staminate (male) flowers (Nwankwo, 2014). The sex separation is not complete since a persisted but low percentage of *monoecious* plant occurs (Akoroda, 1984). The improvement of yam had been limited to the clonal selection (IITA, 1992). However, since the knowledge of floral biology of the yam crop, the controlled production of hybrid seeds required for genetic improvement of food yam plant became possible because of the sufficient understanding of the flowering behaviour in relation to practical techniques for artificial pollination (IITA, 1992). However, lack of flowering yam plants is identified as a problem and a major obstacle to yam breeding work. Degrass (2000) observed that crossing may be achieved under special isolation, but it is often hampered by irregular flowering behaviour among yam plants and insufficient intensity of flowering. Akoroda (1984) also reported that progress in white yam breeding has been hampered by erratic supply of hybrid seeds due to poor fruit sets as a result of low ratio of flowering male to female plants in the population.

Adequate knowledge of the floral behaviour of the yam plants will prevent genetic barriers to successful hybridization. Sufficient information on floral behaviour of hybrid yam genotypes enabled yam breeders to make selection of the genotypes to utilize as parents for effective artificial pollination. It also provided breeders with enough information that facilitated the development of efficient and reliable yam plant germplasm that were gene-banks for yam improvement and enhanced the management of pollination of the crop. A sustained high capability flowering yam plant was also desirable in breeding population, since the continued use of elite clones as parents in yam hybridization programmes depended to a large extent on whether such clones are flowering and producing seeds (Akoroda *et al,* 1985). All these were observed and contributed in the successful breakthrough in the production and release of the first hybrid yam varieties in the early years of 2001.

Another problem faced by Yam breeders during the 1970's to 2000 was that the portion used for planting the yam crop is also the edible portion. A farmer is expected to set aside at least one quarter of his annual harvest to prepare planting material. But during emergencies, farmers tend to fall back on their reserves for survival. The implication becomes almost impossible to re-create new germplasm because flowering varieties has been consumed. Again, yam naturally has a peculiar characteristic of poor response to conventional plant breeding techniques. Yam flowers are borne on separate plants, this make it difficult to synchronize the flowers. When the female flowers are ready, the male flowers are not ready and vice versa (IITA, 2008). Flower *thrips*, the major insects that pollinate yam flowers also usually do a poor job resulting in the abortion of yam female flowers. It was also observed that flowering in yam though genetic, could be affected by environmental factors, elevation and sett or seed tuber size. The yam that flowers this year, may not flower next year and the intensity of flowering could not be predicted. All these impose restrictions on yam hybridization using conventional techniques (IITA, 2008). Advances have been made in studies of reproductive biology of yams especially at the Central Tuber Crops Research Institute (CTCRI), Trivandrum, India, and IITA, Ibadan, Nigeria (Akoroda 1985; Abraham and Nair 1990). Techniques for manipulation of flowering periods to enhance sychronization and extend pollination periods have been established. Anthesis times, periods of pollen viability and stigma receptivity have also been determined for the relevant species. Moreover, storage of pollen from *D. rotundata* in a viable condition at 0% relative humidity and –5 °C for up to one year has been demonstrated (Akoroda 1983). This has the potential to iron out the non-overlapping of male and female flowering phases. In spite of the foregoing, further work is in progress to develop protocols for inducing flowering in non-flowering but agronomically desirable varieties (especially of *D. alata*).

With the improved knowledge of the floral biology of yam, controlled hybridization of the yam crop, either through intra-specific (crosses within a species) or inter-specific (crosses between species)were carried out especially by the International Institute of Tropical Agriculture (IITA) Ibadan from the late 1970,s and 1980's under Dr Asiedu, R. Several control crosses and natural Open pollination were carried out to produce progenies that were field evaluated. This led to creation of variability from which selection were made of yam genotypes with desirable characteristics for various commercial and industrial purposes. Selected yam genotypes were sent for regional trial in various countries. IITA worked with national Programmes in various countries (Nigeria, Ghana, Togo etc) to release these hybrid yam genotypes in those locations.

Despite the importance of yams in the tropics, comparatively little research effort has been devoted to them especially by the National breeding programmes. Major yam producing countries are poor and often unable to fund meaningful research programmes, especially as yam research is extremely difficult and expensive. The long growth cycle produces only one crop a year and breeding work is often hampered by the irregular sexuality of the yam plants. Therefore, the only variation that exits among cultivated yams is that which was present from the native species. Further diversity could now be generated from wide crosses between compatible types, which are now possible because of the present state of the knowledge of the floral biology of the yam plant. (Ngeve, 1999).

Plate 1: Yam hybridization plot

Plate 2: Male yam plant **Plate 3:** Female yam plant

Plate 4 and 5: Yam capsules from female yam plant

Currently, only landraces are in cultivation and this affects yield. The low yield is partly due to limited attempt at breeding the yam crop for higher yield. Again, as a result of population explosion and urban development, hectares of land under cultivations are shrinking. This suggested reasons for the need for higher yielding genotypes from the available land. Higher yield per plant is greatly required.

D. rotundata is a species among the 600 species 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). With the progress so far made the understanding of the reproductive biology of *the yam crop,* the rich varietal diversity within this species were utilized through intra- and inter-specific hybridization for effective genetic improvement of the *Dioscorea* species for higher yields. It is believed that the selection of resultant hybrid genotypes with higher yield potential, appealing tubers, high flowering intensity and improved morphological characters, will contribute to high yielding genotypes of *Dioscorea rotundata* for commercial production.

Early in the 1970's progress was made in the successful crossing of yam botanical seeds by the

International Institute for Tropical Agriculture, Ibadan, Nigeria while The National Root Crops Research Institute (NRCRI) Umudike was being used as the testing/evaluation ground. In 2001, the first hybrid yam genotypes were released by IITA through the NRCRI) Umudike. However, the genetic improvement of the crop at the National level started later in 1995 and1999 when the then Chief breeder Dr Nwachukwu, E.C sent Dr Nwankwo, Innocent .I.M (then an Agricultural Superintendent) to study the genetic improvement of the Yam crop by controlled crossing. (Dr Nwankwo Innocent I.M was also instrumental for the successful artificial pollination of sweet potato in NRCRI Umudike for the first time which led to the release of the first orange fleshed and white fleshed sweet potato in Nigeria in 2012 and 2013 respectively). This led to first establishment of hybridization block in 1999and in 2008, the first bred hybrid white yam (DRN200/4/2) was released by NRCRI) Umudike through Dr Nwachukwu, E.C. Other varieties were released by IITA and NRCRI Umudike in 2009, and 2010. In 2016 one IITA bred variety and one NRCRI Umudike bred hybrid variety were released by Dr Nwankwo, Innocent I.M through the backing of Dr Eke-Okoro, O.N. The same year, NRCRI Umudike registered five landraces for the first time in the history of yam releases in Nigeria. This registration made it possible for these cultivars to be officially recognized as varieties and given official code and could be used as commercial varieties within and outside the country-Nigeria. Table 1 indicated the names of the released varieties, year of release/registration and their outstanding characteristics.

Plate 6: Yam crop growing in the field

The tuber from each seedling is a clone and quite different from each other (as indicated by their roots, tuber and vegetative characteristics). Healthy yam tubers from the yam plants are selected on the basis of desired phenotypical characteristics after adequate testing under field conditions. Diseased and poor yielding clones are immediately discarded. The individuals within a clone have the same genotypical constitution. The selected yam clones are given numbers or names and multiplied by mini-sett techniques or vine cuttings or in the tissue culture. They are then advanced into another stage where their yields will be tested. The pre-luminary yield stage of the yam crop is compared with the normal local variety. The best performers from all viewpoints of economic importance are selected. Next steps are to carry out comparative trials at different regional stations for three years continuously. Hybrids selected are studied for desirable characters. The best ones are selected, multiplied and compared with standard varieties. If found suitable under trials, are named, multiplied, recommended and distributed to the farmers. The time taken for producing a variety from the hybridization block until it is released may be between 10 – 12 years. Nwankwo (2014) reported that yam varieties produced clonally are as stable as pure lines and there is no danger of variations resulting from mendelian segregation. The fear of deterioration is totally reduced and the yam varieties retain their characteristics as such even after many years of cultivation unless mutation occurs and produces bud sports, chimeras and genetic mosaics. He further observed that once the yam plant with hybrid vigour is obtained by hybridization, it can easily be preserved by vegetative propagation in the clonal crops and offers great possibilities of its utilization in each generation. On further clonal propagation of the yam plant, there arises no problem of hybrid seed production every year as is prevalent in those crops propagated only by seed. Hybridization is practiced in yam, but selection among the hybrids is made by clonal selection.

Selection criteria for the developed yam genotypes: Nwankwo (2015) reported that the selection criteria for the improvement of the yam traits (such as number of leaves, plant height, number of tubers and others) that were released are essential. They are important either to the crop or to man, and were desirable. The essential traits of the yam crop include: strong seedlings (at germination), quick early growth, reaction to diseases, reaction to temperature extremes, reaction to drought, poor soils, fertilizer, time of flowering, time of tuberization, multiple tubering, time of maturity, tuber shape flesh colour and other attribute.

The Establishment of Yam Research Programme At International Institute of Tropical Agriculture (IITA) - Ibadan: International Institute of Tropical Agriculture (IITA) Ibadan has a global mandate on yam research and improvement. However, it has to work with the national programmes of countries for their work to be beneficial to the farmers who are at the grass root level. Yam Improvement Programme started in 1971 at IITA led by Dr S.K. Hahn a Korean born breeder. This initiative for yam improvement was based on the work of some botany scientists that some yam varieties flowers and produce viable seeds in nature, but flowering in yams were unpredictable interms of regularity, intensity and seed setting. While some do not flower at all. Male yams flowers profusely and earlier than female yam plants however, synchronization is very poor. Germplasm were collected around West Africa which is

The first successful intra-specific cross was the *D. rotundata* and it was made in 1974 at IITA, and in 1975 Okoli himself independently reported of the germination of open pollinated botanical/true yam seeds (Okoli, 1975). The same year, Sadik and Okereke reported the same success work of artificially pollinated male and female white yam plants and the true seed germination (Sadik and Okereke, 1975).

The objectives of making these crosses were to develop high yielding, pests and diseases resistant varieties. To develop varieties with appreciable culinary quality, low post harvest deterioration, non-staking amongst other attributes. Thousands of crosses were made and considerable number of botanical/true yam seeds was generated.

In 1989, the first hybrid yam genotypes were sent to national programmes in countries like Nigeria and Ghana to be evaluated. This work did not last long. This was because Dr Larry Stifiel during his tenure as Director of IITA between 1988 to 1991padlocked the breeding work on yam and declared it uneconomical. This was as a result of Dr Paul Dorosh an American post Doctorial work in favour of FAO's Agricultural production and consumption data entitled "The economics of Roots and Tuber crops in Africa" (Dorosh, 1988).

In 1991 Dr. Stifiel left IITA. Yam research Programme was restored. Dr Robert Asiedu, a Ghanaian born researcher was redeployed from Cassava to lead yam research programme of the IITA. In 1992, Dr Asiedu made thousands of crosses and generated considerable number of seeds that were planted in nurseries. The clones were field tested and genotypes were selected for further evaluation. Asiedu's yam improvement work was aggressively pursued that it

the centre of origin of white yam (*D. rotundata*) and outside West Africa.

The germplasm were evaluated to understand the environmental and biological factors that promote flowering in yam. Some factors noted were time of planting, sett or seed tuber size, health of planting material, soil moisture, humidity, soil fertility, photoperiod and elevation.

was jokingly say that he planted more yams than he could harvest.

In 2001, the first three hybrid yam genotypes that were superior in terms of yield and pests and diseases resistance to the existing white yam landraces were officially released to farmers in Nigeria. Other releases followed in subsequent years. The releases were made through National Root Crops Research Institute, Umudike, the Institute that has the national mandate for the genetic improvement of roots and tuber crops, tuber yield, number of tubers per stand, tuber flesh colour, tuber flesh oxidation, tuber dry matter yield, storage characteristics, processing and consumption quality, consumer preference (size, colour, taste) spines on vines, roots and on tubers, spineless vines, roots and tuber qualities for mechanization etc. When additional traits in yam products and of the yam plant are needed, new characteristic will be introduced especially from the wild relatives of the yam plant. The trait is then incorporated into the yam cultivars. Each year starting from 1970 till date new traits are added in the criteria required for yam selection. This can be done through hybridization to create a new variety. Hybridization is the method in which two or more plants of unlike genetic constitution are crossed together to produce a new hybrid crop. The yam plants which are crossed together may belong to the same species or different species. Chaudhari (2005) observed that hybridization is used for crop improvement with three main aims: - to combine all the good characters into a single variety, to increase or broaden the range of genetic variability by introducing various recombination of characters and to exploit and utilize the hybrid vigour. All these three aims are utilized to improve the yam crop.

Table 1: Characteristics of released/registered yam varieties

S/No	Variety name	Original name	National code	Outstanding characteristics	Agro-ecological zone	Year of release	Year registry
1	TDr89/02677	TDr89/02677	NGDR-01-1	Stable yield, very good cooking qualities, cream tuber parenchyma, 20% tuber dry matter content.	Forest and Southern Guinea savanna	2001	2001
2	TDr89/02565	TDr89/02565	NGDR-01-2	Stable yield, very good cooking and pounding qualities, cream non oxidizing parenchyma, 35% tuber dry matter	Forest and Southern Guinea savanna	2001	2001
3	TDr 89/02461	TDr 89/02461	NGDR-01-3	Stable yield, very good cooking qualities, cream tuber parenchyma, 26.7% tuber dry matter content.	Forest and Southern Guinea savanna	2001	2001
4	TDr 89/02665	TDr 89/02665	NGDR-03-4	Stable yield, very good cooking and pounding qualities, cream non oxidizing parenchyma, 35.3% tuber dry matter	Forest and Southern Guinea savanna	2003	2003
5	TDr89/1213	TDr89/1213	NGDR-03-5	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, tuber dry matter 29.8%	Forest and Southern Guinea savanna	2003	2003
6	TDr89/01438	TDr89/01438	NGDR-03-6	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, tuber dry matter 29.3%	Forest and Southern Guinea savanna	2003	2003
7	TDr95/01924	TDr95/01924	NGDR-03-7	Stable yield, very good cooking and pounding qualities, white non-oxidizing parenchyma, tuber dry matter 32.8%	Forest and Southern Guinea savanna	2003	2003
8	DRN200/4/2	DRN200/4/2	NGDR-08-8	High yielding, pests and diseases tolerant, very good for fufu, frying and boiling. (35t/ha)	Yam zones of Nigeria	2008	2008
9	TDa98/01176	TDa98/01176	NGDA-08-9	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, suitable for both rainy and dry seasons yam production. (26-30t/ha)	Yam zones of Nigeria	2008	2008
10	TDa98/01168	TDa98/01168	NGDA-08-10	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, pests and diseases tolerant, good for pounded yam, frying and boiling. (24-28t/ha	Yam zones of Nigeria	2008	2008

S/No	Variety name	Original name	National code	Outstanding characteristics	Agro-ecological zone	Year of release	Year registry
11	TDa98/01166	TDa98/01166	NGDA-08-11	High yielding, pests and diseases tolerant, good for pounded yam, frying and boiling, suitable for both rainy and dry seasons yam production. (26-30t/ha)	Yam zones of Nigeria	2008	2008
12	TDr95/19158	TDr95/19158	NGDR-09-12	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (29.4t/ha)	Yam zones of Nigeria	2009	2009
13	TDr89/02602	TDr89/02602	NGDR-09-13	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (31.5t/ha)	Yam zones of Nigeria	2009	2009
14	TDr89/02660	TDr89/02660	NGDR-09-14	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (31t/ha)	Yam zones of Nigeria	2009	2009
15	TDa00/00194	TDa00/00194	NGDA-09-15	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (37.5t/ha)	Yam zones of Nigeria	2009	2009
16	TDa00/00104	TDa00/00104	NGDA-09-16	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (30t/ha)	Yam zones of Nigeria	2009	2009
17	UMUDa-4	TDa00/00364	NGDA-10-17	High yielding, good for Amala, pounded yam, frying and boiling (33.3t/ha)	Yam zones of Nigeria	2010	2010
18	UMUDr-17	TDr95/19177	NGDR-10-17	High yielding under dry season yam cropping system. (30t/ha)	Yam zones of Nigeria	2010	2010
19	UMUDr-18	TDr89/02475	NGDR-10-19	High yielding, pests and diseases tolerant, very good for yam fufu, frying and boiling. (31t/ha)	Yam zones of Nigeria	2010	2010

S/No	Variety name	Original name	National code	Outstanding characteristics	Agro-ecological zone	Year of release	Year registry
20	UMUDr-20	98/00933	NGDR-10-21	High yielding, light yellow flesh tuber characteristics, Widely adaptable to the low fertility yam zones of Nigeria, Tolerant/resistant to Yam mosaic disease, Leafspot and Anthracnose (39.8t/ha)	Yam zones of Nigeria	2016	2016
21	UMUDr- 21	99/Amo/064	NGDR-10-22	Cut tuber is light purple at the proximate region , Widely adaptable to the yam zones of Nigeria, Tolerant/resistant to Yam mosaic disease, Leafspot and Anthracnose High yielding with sparse fine hairs on tuber surface (43.9t/ha)	Yam zones of Nigeria	2016	2016
22	UMUDr-22	Obiaoturugo		Yam virus disease resistance, Stable yield, Very high yielding, Good for fries and chips, Broadly adapted, Good for pounding yam fufu, High dry matter, 27.78t/ha, DMC 29.18%,	Yam zones of Nigeria	2016	2016
23	UMUDr-23	Amola		Good cooking and pounding quality, cream tuber parenchyma, Very high yielding, Good for fries, Widely adapted (21.6t/ha), Dry matter %: 30.60	Yam zones of Nigeria	2016	2016
24	UMUDr-24	Hembakwasi		High yielding, Yam virus disease resistance, High zinc content, Good for white flour, Good for pounding fufu, 29.94t/ha, DMC 40.15%,m	Yam zones of Nigeria	2016	2016
25	UMUDr-25	Ekpe		Early maturing and early bulking, Pests and Disease tolerant, Very High yielding, Widely adapted, Very good cooking quality, good for pounding (23.21t/ha), DMC 34.37%,	Yam zones of Nigeria	2016	2016
26	UMUDr-26	Aloshi		Stable yield, good cooking and pounding quality, non-oxidizing parenchyma, Pests and diseases tolerant, Good tuber storability, 27.6t/ha, DMC 26.96%,	Yam zones of Nigeria	2016	2016

Creation of heritable variation in the developed yam genotypes: The heritable variation in the yam in the released yam varieties were created and as Chaudhari (2005) pointed out, by crossing unlike individuals give rise to entirely new yam varieties which showed variations in their characters as compared to their parents. This variation is not due to creation of any genes but simply due to mendelian recombination of the genes already present in the population. Such variations are heritable and form source of evolution in plant kingdom. Chaudhari (2005) stated that the production of superior varieties resulted when most of the economic characters of crop plants result from interactions of many genes scattered over several chromosomes in different yam plants. Hybridization brings all these useful factors together and concentrates them into a single yam variety. Thus, a yam variety possessing all the desirable characters such as high yield, good quality, resistance to diseases and pests, drought etc was produced. Secondly, the yam variety suited to every condition and need by man can be evolved. Thus, the yam varieties produced by hybridization are more vigorous exhibiting hybrid vigour.

The yam plants propagated by seeds result in great variations in the populations. The hybrid seedling on maturity is heterozygous. On account of this, the yam plant are propagated using the tubers and their vegetative parts (e.g. the vines) in each generation and crop population in them is composed of direct vegetative descendants from different plants (Chaudhari, 2005). All the vegetative/tuber descendant of a single yam plant are together known as clones.

The developed Yam genotypes as a clone: The yam genotypes developed and released may remain unchanged genetically for a very long time. This is because of the yam crop as a clone can be propagated by cloning. Chaudhari (2005) defined a clone as a variety or group of plants obtained vegetatively from a single plant. All the plants of a clone descended by mitosis through the process of vegetative propagation. All the members of yam clone are identical. There is no variation within a clone. All the individuals of a clone are in fact the pieces of a single plant and therefore are genotypically and phenotypically identical. The cause of this resemblance is their origin and development from the single parent plant by mitotic cell division in which there is no mechanism that permits any change in the daughter cells from the mother cell. The variations in the daughter cell occur only during meiosis due to pairing and crossing over of homologous chromosomes, separation of paired chromosomes and union of gametes from different plants which do not take place in the clone. The members of yam clone are identical i.e. they have the same genotype, bred pure to parental types and have the characteristics of producing genetically uniform progenies. Any variation of them is wholly due to environmental differences. When environment is highly uniform, differences between the yam plants may be small, and when environment is very variable, the differences may be very large. No matter whether they are small or large, they are only phenotypically, and not inherited differences.

Genetic variation in a yam clone arises only due to bud or somatic mutations which are very rare if at all there are, they are of no agronomic importance because of very low frequency of their occurrence. (Chaudhari, 2005).The variation between populations of different yam clones is due to the differences in the genes as well as environment. Genetically, all the members of the yam clone are heterozygous i.e. all the members in a yam clone are alike phenotypically but genotypically they are not. The parental plant in vegetatively propagated crop is always heterozygous which can be easily exploited for useful objectives. Variability in yam plant is seen from the variations arising among the seedlings raised by botanical seeds of the yam plant.

Again, yam clones are stable as pure lines and no segregation or variations occurring in them in their future generations even after many years of cultivation and vegetative propagation. The yam clones retain their original characters as such. That is why many yam crops evolved many years ago and propagated vegetative still retain their desirable characteristics as shown in the Table 1.

The clonal yam population, being alike genotypically and linear descendants of a single plant resembles the pure lines just like the identical twins. They differ from them, however, only in two fundamental ways. First, the various plants of a sexually reproduced pure-line are homozygous and genotypically alike except mutation, while the members of a clone though genotypically alike except mutations are always heterozygous. Second, the repeated self-fertilization in a heterozygous plant result in the production of a number of pure lines, while only one clone is produced by repeated vegetative propagation from one heterozygous plant, apart from somatic mutations. The importance of the yam tuber or vine is that it is used as a clone and is the only means of perpetuating an already improved and superior yam variety.

Stability of the developed hybrid yam genotypes: The yield of the developed yam genotypes had to be stable across the agro-ecological zones of the country. According to Dixon *et al* (1994) a stable cultivar is one whose yield varies little from year to year, and adaptable as one whose average yield over years varies little across locations. From 1990 onwards, yam clones were evaluated for yield stability across agro-ecological zones. As Sagoe *et al* (1995), emphasized, multi-location trials are fundamental in developing and identifying clones which are stable, widely adapted, high yielding and resistant to diseases and pests. Clones tested in a wide range of environments exhibited a Genotype by Environment interaction which usually poses serious problems in comparing their performance. Cassava (*Manihotesculenta* Crantz) although widely adapted, has limited adaptation being very sensitive to GXE interaction. With a GXE interaction, the yam breeder faces major problems in comparing the performance of cultivars across environments. Since the interactions reduce the correlations between genotypes and phenotypes, it results in weak inferences from the field data relevant to crop improvement which reduces the progress of breeding outside a target environment. Breeding for genotypes which are spatially stable can enhance its efficiency. In addition to high yield means, statistics for assessing the stability of a genotype's performance in different environment and year is necessary to assist the yam breeders in selecting superior cultivars with consistency of performance (Ngeve, 1994). This has to be incorporated in yam breeding.

Combined analysis of variance detects GXE interactions. It however does not describe the different responses of the yam clones to the environment. A variety of statistics for measuring the various concept of stability or the sensitivity of a yam genotype to environmental changes exist. Shukla (1972) developed estimate of stability variance which partitions the GXE sums of squares into components attributed to individual cultivar, and also gave a criterion for testing the significance of the stability variance. The more widely used stability statistics involve regression (Ngeve, 1994). Finlay and Wilkinson (1993) used linear regression coefficient of determination (r^2) of mean genotypic yield, transformed to logarithmic scale, on the population mean. Cultivars with low b – values were considered stable and absolute phenotypic stability was expressed by b = 0. Unstable cultivars were those with high b – values. Eberhart and Russel (1966) refined the regression approach by regressing mean of yield of all cultivars on an environmental index calculated as the mean yield of all cultivars in one environment minus the mean of all environments. According to them, a stable cultivar is one with high mean yield of b = 1.0. Bacusmo *et al* (1988) compared Shukla (1972) parameters with some of the stability methods involving regression (Ngeve, 1994). They found that the methods were highly correlated and cultivars described as stable by one method were also judged to be stable by the other (Eberhart and Russel 1966).

Omolaja and Esan (2006), considered stability parameters when regression coefficient (b) was close to unity. A study of genotype x environment can lead to successful evaluation of stable yam genotypes which could be used in future breeding programmes (Paroda *et al* 1973). Finlay and Wilkinson (1993) considered linear regression slope as a measure of stability. Eberhart and Russel (1966) emphasized the need to consider both the linear and non-linear (sb) components of genotype x location interaction in judging the phenotypic stability of a genotype. Later, Samuel *et al* (1970) and Paroda and Hayes (1971) emphasized that the nonlinear regression should simply be regarded as a measure of the response of a particular genotype, whereas the deviation around the regression line (sb) should be considered as a measure of stability, the genotype with the lowest deviation being the most stable and vice versa. Therefore, to judge the stability of a yam genotype, due consideration were given to its mean and linear performance. An ideal yam variety that satisfied these conditions must have the highest yield over a broad range of environments, and a unit regression coefficient (linear) and deviation mean square (non-linear) of zero as recommended by Eberhart and Russel (1966) and were recommended for release.

Other stability indices used included coefficient of variability across environments (Francis and Kannenberg, 1978). So in a GXE analysis, a desirable cultivar should have low coefficient of variation (CV) and high mean yield. Several breeding programmes use these stability parameters as selection criterion in cassava development since edaphic variation within seasons and agro-ecological zones are significant (Ngeve, 1994, Otoo *et al*, 1991). So the yam genotypes released as varieties from 2001 to 2016 (as shown in Table 1) were subjected to stability statistics before released.

Favourable climatic conditions are critical for commercial cultivation of crops in any location. Rainfall, temperature and soil pH are the key parameters determining the success of cultivation of crops (Fulani and Okelana, 1980). These are identified as some of the reasons why yam performs best in yam growing zones. Moreover, these yam zones have slightly acidic deep and well drained soils with high organic matter content (Onwueme, 1978). The average annual rainfall prevailing in the location were among the highest (range of 1800mm to 2085mm) with low average daily temperature within latitude 5^0 6'' N. The investigation of the GXE estimation of heritability and identification of stable yam clones were used to breed and select high yielding and stable yam genotypes as the best choice for the farmers in these environments.

Yam development through seed tuber multiplication

Development of seed yam through vine cuttings: Despite the progress so far made in breeding the crop over the years and the importance of the crop in the economy and socio-cultural life of many Nigerians, the crop faces a lot of challenges that reduce its potential to meet farmers, industrialists and consumers' needs (Nweke, 2016). Nweke (2016) reported that these challenges include: unavailability of seed tuber at affordable price, pests and diseases infestation, lack of interest in its research as a result of its long lifespan of seven to nine months and as a result, the few available tubers in the markets are costly and none is available for other industrial value additions. The yam plant is traditionally propagated by the use of the tuber which is the edible part of the yam plant. Seed tubers are used for ware yam (Table yam and Ceremonial tuber) production. The seed tuber for ware tuber production is not available and affordable by the farmers. However, the tuber has a very low multiplication rate when compared with cereals which is of the ratio of 1:200 while yam is 1:6 (Mbanaso *et al*, 2011). In addition to the low multiplication ratio, is the crop's long growth period of seven to nine months depending on the variety and tuber size plus two to three months dormancy period after field senescence. The low multiplication rate contributed to the expensiveness of seed tuber which is used for propagation of ware yams which consist of the table yam and ceremonial yam (Nwaeke, 2016). Also, the low multiplication rate of the yam crop hinders the none availability of improved high yielding varieties into the hands of many farmers who produces this prestigious carbohydrate for the masses. As a result, newly released yam varieties takes longer period to get into the hands of end users and on the table of consumers. Yam cultivation for ware tuber yam production is still being carried out by the use of seed tubers.

The traditional seed tuber production in Nigeria is divided into two methods. The first method is the milking of the tubers of the yam plants without destroying the root system. This provides the early ware yam tubers for consumption. The parent plants then regenerate small tubers which are used as seed tuber for the following planting season, and this can only take place for early bulking yam plants (Onwueme and Sinha, 1991). The second method is the separation of seed tubers from the ware yams after harvesting of the entre yam field. Tubers are sorted by sizes. Small ones are used for seed tuber (<1000g), medium size ones are for table yam (>1000g < 3000g) and very large ones as ceremonial yam tubers (>3000g). This method also significantly contributes to low seed tuber production. These are the methods used in the production of seed tubers for ware yam production since the 1923's and even to date in some areas.

Mignouna *et al* (2014) therefore reported that there has been a long history in the propagation of yams vegetatively. He further observed that this method has been a limited application in yam multiplication. Correl and his co-workers as far back as in 1955 and Martins and Gaskins in 1968 demonstrated that the bud in the leaf-axils on the vines when cut could be used for the field production of ware tubers of water yam (*Dioscorea* *alata* L) (Correl et al, 1955). Njoku in his work on vine cuttings in 1963 showed that vine cuttings could root,

produce new shoots and form tubers within three to eight weeks after planting in the soil (Njoku, 1963). Several other workers (Cabanillas and Martins, 1978 and Vandader Zaag and Fox 1981 and Nwoke, 1986) have reported that vines with leaf-axils of five species of *Dioscorea* (*D*, *rotundata* Poir, D*. cayenesis* Lam., D*. alata* L., *D. dumetorum* Pax and *D. bulbifera* L) could be used as vine propagation for seed tuber propagation. However, none of these researchers demonstrated that vine cuttings could be used to enhance the rapid multiplication rate of the yam plant for commercial seed tuber production. Otoo and his co-workers (2012) agreed that the low multiplication ratio of 1:6 (from double harvesting of yam) and 1:40 (from minisetting technique) compared to 1: 500 for Cereals call for the need for an efficient technique for increasing the multiplication ratio of the yam.

Improving the efficiency of the tuber seed yam production will increase the multiplication rate of seed tubers from single mother yam tuber. This will lead to sustainable high quality seed yam tuber on a commercial scale and provide disease free seed yams at affordable price (Nwankwo et al., 2017).To solve this problem, NRCRI, Umudike and IITA Ibadan in the year starting from the 1980's embanked on series of multiplication techniques. Some of which is worthy of being mention.

The development of minisett technique for breeder's seed tuber yam multiplication: The development of the minisett technique by the National Root Crops Research Institute, Umudike for rapid multiplication of seed tuber yam have revolutionalized seed tuber yam industry especially from the year 2000's. Farmers have now been offered a reliable method of large scale seed tuber yam production (Nwankwo et al., 2017).A minisett is defined as a cut sett of about 25 grammes or less. Minisett technique was developed to overcome the challenge of unavailability of good quality seed tuber yam by improving the multiplication rate of white yam from the multiplication ratio of 1:5 to 1:30 (Orkwor et al., 2000). The minisett technique involves the cutting of ‘ware yam tuber into small setts (minisetts) of 25g which must possess a reasonable amount of peel (periderm) from which sprouting can occur. The cut setts are treated with chemicals such as pesticides or fungicides to prevent damage from diseases and pests, planted, and managed to produce small whole seed tubers. The seed tubers in turn are planted to produce ware tubers for food. There is a positive correlation between the size of the minisett and the size of the seed tuber produced. There are varietal differences in the performance of minisetts; however, the same size of different varieties may perform differently.

Ogbodu (1995) and Anuebunwa et al. (1998) reported that adoption rate of the technology was still below 40% and that farmers showed only partial adoption. Reasons given by farmers for the poor adoption were; the size of the minisetts (25g) is too small and that the technology was developed under monoculture, while most farmers in the humid tropics practice inter cropping (Ikeogu and Ogbonna, 2009). In the year 2000, Ikeorgu and his co-workers modified the yam minisett technique and recommendations were made more elastic such that farmers who wish to produce seed yams of 500g and above could use minisett of 35g-45g (Ikeogu *et al*., 2000).Now, farmers are provided mini tubers (Ikeogu and Ogboma, 2009) for planting according to their production objectives, thereby eliminating the fears that the minisett would delay the production cycle.

The development of vine cutting technique for breeder seed tuber yam multiplication: The vine cutting propagation which was demonstrated in 1963 (Njoku, 1963) came into focus in 1990's for use in seed tuber multiplication. Nwankwo et al (2017) reported that an experiment which consisted of first; the establishment of the mother plants of white yam varieties which were Obiaoturugo, Amola, Gbagu, Aloshi, Hembakwasi, Ogini, Ekpe, Ame and TDr89/02665) from which vines were collected and established in the screen house using micro-tubers weighing 25g each. The tubers were planted in 20 perforated plastic buckets of size 8 × 12cm each, filled with sterilized top soil and arranged in batches of twenty per variety in the screen house. They were watered twice a week with watering can until they sprout. The vines were trained on ropes to the top of the screen house. The vine tips were cut back at two months after planting to induce lateral branching from where vines were cut for pre-rooting. Three actively growing mother yam plants from each variety (that were 20 in a batch) were tagged for vine collection by cutting it with sharp Scissors. Vine cuttings were collected from succulent none lignified lateral branches of the tagged mother yam plants for successful pre-rooting in nursery bags three months after planting (MAP) and were cut for every other three months for a period of nine months.

Nursery bags with size 6 x 4cm were filled with a mixture of carbonized rice husk and topsoil in the ratio of two parts of carbonized rice husk to one part of topsoil. The nursery bags were arranged in batches per variety per as many cuttings as to be collected per a particular period for each of the varieties. The arranged nursery bags were watered. The collected vines from the tagged mother plants were prepared by cutting the vines into one cutting with one node containing an axillary bud. The length of the vine above the node was 1cm and 2cm below the node to allow for firm attachment into the soil at the time of planting. The cut vines with nodes were soaked in water for five minutes to reduce transpiration rate and enhance the survival of the cuttings. The vine cuttings were planted by inserting the longer side of the cutting into the medium in the nursery polybags with the nodes deep into the soil and the leaves above the soil level.

After planting, the vine cuttings were watered and kept moist by watering every two days in a week. The numbers of vine cuttings planted per variety were recorded. The vine cuttings started rooting and shooting twenty one days after planting.

The pre-sprouted vines were transplanted to the field. Also one perforated plastic bucket of the same size filled with sterilized top soil was planted with one micro tuber of the same weight of 25g using the national check variety (TDr89/02665) and was used as the control. At time of transplanting to the field, both the pre-sprouted vines and the potted yam plant used as control were transferred to the field and planted.

Ratio of vine cuttings collected from mother yam plant: The data on the ratio of number of vine cuttings produced per variety per stand and number of rooted vines per variety transplanted to the field are presented in Table 2.

Table 2 showed that nine mother yam stands of various yam varieties yielded a combined total of 504 vine cuttings. That is 9 mother yam stands is to 504 vine cuttings which was equivalent to 1 mother yam plant to 56 vine cuttings. Out of the total of 504 vine cuttings, the highest ratio of vine cuttings was produced by the variety Gbagu, which was in the ratio of one mother yam plant is to 63 vine cuttings. This was followed by Amola with one mother yam plant in to 59 vine cuttings while the least of vine cuttings collected was from Ekpe which yielded the ratio of one mother plant in to 57 vine cuttings. When compared to the check/control, one mother plant produced one yam plant.

Table 2: Mean ratio of vine cuttings per stand of mother plant per variety, number of rooted and field establishment per variety for the two years combined.

Names of Varieties	Ratio of vine cuttings per mother plant	No. of rooted vines	Number of rooted vine cuttings transplanted to field	Number of field survival
Obiaoturugo	57	51	51	51
Amola	59	49	49	49
Gbagu	63	58	58	56
Aloshi	53	51	51	51
Hembakwasi	53	53	53	53
Ogini	57	51	51	51
Ekpe	51	45	45	45
Ame	57	52	52	52
TDr89/02665	56	56	56	56
Total	504	466	466	464
Mean	56.0	51.1	51.1	51.6
S.E.D	2.6	2.51	2.51	2.54
Level of sig.	P<0.01	P<0.05	P<0.05	P<0.05
Control(02665)	1	1	1	1

Source: (Nwankwo *et al,* 2017)

The cloned vine cuttings that sprouted and transplanted in the field were 465 vine cuttings; however, 464vine cuttings survived in the field as yam plants which produced tubers that were harvested when the yam plant matured. The highest number of vine cuttings that rooted, transplanted and survived in the field was Gbagu and TDr/89/02665 respectively. Gbagu variety gave 58 vine cuttings per mother plant but 56 survived in the field to produce tubers followed by the variety TDr/89/02665 which had 56 rooted cuttings per mother plant and transplanted to the field which at maturity produced 56 tubers while the least ratio was from Ekpe variety. The number of vine cuttings collected from a single mother yam plant of Ekpe was 45 vine cuttings which was also produced 45 tubers at maturity. However the Check/control variety planted with the same 25g seed tuber produced one tuber at maturity. This number was very low when compared with the varieties multiplied with their vine cuttings.

Number of tubers per vine cutting per variety: Each matured stand of vine cuttings in the field produced one tuber. Almost all the stands of vine cuttings of the various yam varieties produced one tuber per vine cutting except Obiaoturugo that produced 1.1 tubers per stand. The grand mean showed that the vine cuttings produced one tuber per vine cutting. However, the Check/control which is the traditional method of propagating yam for tuber production with one tuber per stand (without collecting vine cuttings from the mother plant for further propagation) produced one tuber per mother plant for the period of nine months.

Tuber Size: The tuber length ranged from 4.4cm from tubers produced by the variety Ogini to as long as 7.3 cm for tubers produced by the variety Obiaoturugo. The grand mean was 6.4cm. However, the tuber size from the control/ traditional method of tuber propagation had length of tuber of 9.0cm from the control while the tuber diameter was 6.0 cm. This showed that seed tubers from vine cuttings are sizable for use as Table yam (yam tuber for domestic consumption).

Multiplication ratio of the cloned vine cuttings: The results of the ratio of one stand of mother yam plant to the number of vine cuttings and number of tubers produced per twenty mother plants of the nine varieties of the white guinea yams planted in the screen house are presented in Table 3.

Table 3: The multiplication ratio per stand and per twenty mother yam plants per variety planted in the Screen house for fine cutting

Varietal names	Ratio of vine cuttings to one mother plant	Total number of seed tubers harvested/ Variety	Number of mother yam plants in screen house	Estimated total number of seed tubers from various varieties
Obiaoturugo	51	54	20	55080
Amola	49	51	20	49980
Gbagu	56	56	20	62720
Aloshi	51	51	20	51000
Hembakwasi	53	53	20	54060
Ogini	51	51	20	52020
Ekpe	45	46	20	41400
Ame	52	52	20	54080
TDr89/02665	56	58	20	64960
Total	464	472	180	39,166,560
Control	1 tuber	1	1	1

Source: (Nwankwo *et al*, 2017)

Table 3 showed that a total of 180 yam plants from 9 varieties, cloned up to 464 yam plants gave various tuber yields with a total of 39,166,560 tubers for seed tuber yam production within one year. When compared with the control, only one tuber was produced within the same year as seed tuber. This indicated that vine cuttings could be used to enhance the rate of seed tuber multiplication of yam varieties for commercial seed tuber yam production.

According to the research Mazza carried out in 2009 and Nwankwo et al in 2017 it proved that progress has been recorded with vine cutting technique (Mazza *et al*., 2009). Sett production through yam vine cuttings increases the multiplication of clones beyond levels possible through conventional use of tuber sett (Wilson, 1978), and a lot of tubers need not be reserved for planting purposes (Akoroda and Okonmah., 1982).

Using single-node cuttings, procedure has been developed for the propagation of virus-free tested clones of yam. Another two step propagation developed for yam involves, placing single-node cuttings in a liquid culture medium for 1 month to induce multiple shoot formation, followed by sub culturing the node cuttings in solid media for distribution. Virus-tested clonal materials are micro propagated and distributed on request to national programmes as plantlets and microtubers of yam (Ng, 1992).

Seed tuber multiplication through the aeroponics systems: Aeroponics system is developed to address the limitations in the low multiplication ratio of yam in other techniques such as the minisett technique, vine cutting technique, tissue culture micro-propagation technique and others. The Aeroponics system was developed for the rapid high ratio quality seed tuber production. Aeroponics system is a method of growing plants in a soilless environment with very little water as defined by Carter in 1942 and reported by Maroya et al (2014). However, Nugali et al (2005) defined Aeroponics as a system where roots are continuously or discontinuously grown in an environment saturated with fine drops (a mist or aerosol) at nutrient solution.

In yam seed tuber production, a 50g tuber sett from either the head, middle or tail is potted in polybags in the screen house to generate vines for potting on the tables in the Aeroponics system. In the Aeroponics system, one node vine cuttings from 120 day old yam plants were planted each in small black plastic bag for rooting. The pre-rooted vines were transplanted to the boxes in the Aeroponics of which each contained 49 holes. The boxes are enclosed areas known as root chambers. The chambers protect the roots from light and hold the nutrient/water solution that feeds them. A pump pushes the nutrient solution from underground tanks through a piping system into the boxes where it sprays through series of nozzles inside the boxes as a fine fog directly onto the roots. The excess nutrient solution falls back and returns to the nutrient tank and to be circulated again every 15 minutes. By this method yam plant roots absorb nutrients more efficiently in the mist form. The potted vines grew shoots and minitubers forms in the boxes. The generated vines were cut every 3 months and potted in the shaded screen house for rooting and to be transplanted to the field where it stays until senescence.

The microtubers produced by the vines growing on the box are harvested periodically and are planted to produce seed tuber for ware yam production. The periodic harvesting of the tubers from the inside boxes prolongs the lifespan of the growing yam plants on the tables. However, weight of minitubers harvested from the boxes may range from 0.2 to 2.7g (Maroya et al, 2014). The minituber generated from the boxes could be used for further seed tuber development for ware yam production. The potential of Aeroponics system for high ratio seed tuber production could be illustrated in the Table 4 using the experiment conducted in 2016 at

National Root Crops Research Institute, Umudike Aeroponics Systems.

The total of 1300 vines was collected with a mean of 130 vines generated from 490 holes with a mean of 49 holes per table in the Aeroponics systems. The total number of seed tubers generated from the vines from the 10 varieties was 63,708 seed tubers with a mean of 6370.8 seed tubers per year. That was why the technology is called Rapid high seed tuber propagation ratio.

Table 4: High ratio multiplication rate of the Aeroponics System

Varieties	Average number of vines collected per variety	Number of holes on the Table	Total number of seed tubers generated per year
Obiaoturugo	142	49	6958
Amola	120	49	5958
Hembakwasa	160	49	7840
Ekpe	130	49	6370
Aloshi	117	49	5733
Alumaco	102	49	4998
Akuru	168	49	8232
Awada	118	49	5782
UMUDr/022	121	49	5929
TDr/98/02665	122	49	5978
Total	1300	490	63708
Mean	130	49	6370.8

Source: (Nwankwo, et al, 2017)

Though the system is rapid in yam multiplication, it has few challenges. It is highly technical and requires expertise. The whole system requires high sanitation to avoid disease and pests infestation. It requires less influx of people to avoid disease entrance. The fertilizer requirement is of special mixture in solution and requires professional and technical approach. Screen house is necessary for potting the vines before transplanting to the field. The crops in the field require irrigation facilities for crops to grow to full maturity. Workers and visitors should be disinfected before touching the crop which may be impossible. It is not a technology for smallholder farmers. Constant power supply is a must. The whole system requires expertise construction and handling (Maroya, 2014).

Yam development through techniques for seed yam/tuber cleaning

Yams are vegetative propagation and as they grow by crawling on the soil surface and climbing on the stakes over the years, they accumulate lots of pathogens which in most cases are systemic. These pathogens cause the breakdown of yam crop leading to low yields. As a result, the yam crop needs cleaning in most cases to obtained disease free seed tuber as planting material. Cleaned seed tubers are healthy, vigorous, produce very high yielding tubers and have the tendency to withstand the effect of pests and diseases. Cleaning of seed tubers with modern methods increased from the year 2000 to meet up the demand of quality declared seed. These cleaning can be done using one of the techniques mentioned below:

Tissue culture technique: Seed yam/tuber could be cleaned through Tissue culture technique. Yam propagation is by vegetative and slow. It encourages a build-up of diseases, especially within the existing informal seed system, causing significant yield losses. The slow rate of propagation does not facilitate genetic improvement owing to the limited number of plants produced per year on which selection is based. The tissue culture technique was developed for cleaning and producing disease free yam plantlets. This technology involves the culture/growth of small plant parts in laboratory containers such as test tubes in a nutrient mix medium to regenerate the complete plant (called plantlets). This research option has the advantages of a controlled laboratory environment, not susceptible to changing weather conditions, so that production cycles can be planned. Clean, high quality and uniform plants are produced (Yam and Arditti 2009) from otherwise infected mother plants because small uninfected plant parts are cultured.

Temporary immersion bioreactor system: Balogun *et al*. (2014) reported that Temporary Immersion Bioreactor (TIB) technology is a propagation system that grows plants rapidly by immersing yam plantlets intermittently in liquid nutrients in sterile laboratory containers (bioreactors). The system is propelled by air flow under pressure. In temporary immersion, the cultures are immersed in the medium for a pre-set duration at specified intervals. Each unit is a bioreactor – an enclosed sterile laboratory environment – provided with inlets and outlets for air flow under pressure. The advantages of bioreactors include an increased culture multiplication rate, faster culture growth, a reduction in medium cost and also in energy, labor and laboratory space. The increased rate of multiplication and growth primarily reflects the effect of a liquid medium. The elimination of gelling agents (e.g., agar) reduces medium cost. In bioreactors, the culture density in liquid media is much higher than in the conventional vessels with semisolid media. This technique essentially helps in cleaning vines for seed tuber multiplication.

Somatic embryogenesis: Quiroz-Figueroa et al (2006) described somatic embryogenesis as a process where a plant or embryo is derived from a single somatic cell or group of somatic cells. Therefore, somatic embryos are formed from plant cells that are not normally involved in the development of embryos. They are merely ordinary plant tissue and no endosperm or seed coat is formed

around a somatic embryo. Somatic embryos are produced in vitro. The somatic embryo tissues are place on either solid or liquid nutrient media which contain plant growth regulators. Shoots and roots are formed, allowing them to form a whole plant without culturing on multiple media types. Somatic embryogenesis has served as a model to understand the physiological and biochemical events that occur during plant developmental processes as well as a component to biotechnological advancement This method can be used to clean yam plant of diseases especially virus diseases.
Virus indexing tools: The selection of virus-free, clean seed yam/tuber production requires the use of virus indexing tools. Ampofo et al (2010) observed that yam viruses are diverse and available diagnostic tools fail to detect certain viruses. This poses serious problems for virus-indexing laboratories as material free from virus particles and symptoms can, when stressed, become infected. Therefore it is essential to improve existing diagnostic tools for broad-specific detection of viruses. This is because viruses are systemic and may not be detected by visual means.

Yam development through agronomic packages

Development of Non-Stake Yam Genotypes: The on-going research at the National Root Crops Research Institute, Umudke in collaboration with other research Institutes has directed attention to the development of non-stake yam (Bassey and Nwankwo, 2017). Staking has been considered to increase cost of yam production. Vegetation is now constantly removed which result in lack of staking materials (Manyong *et al.,* 2001) or insufficiency and high cost of staking materials. It also requires transportation of stakes from far distances or locations to the farm and this too reduces the profit margins of farmers engaged in yam production. Staking is also time consuming and labour intensive (Tomothy and Bassey, 2009) which in turn impinges on the profit which the farmers would have realized. For these reasons, Manyong *et al.* (2001) and Nweke *et al* (1991) consider yam production as a non-profitable business. Therefore, yams have been considered mainly as “aman's crop”. In the year 2002, the NRCRI Umudike Yam Breeding Unit embarked on the breeding and selection of yams for non-staking potentials in the development of farmer’s friendly technology. This is to encourage more farmers to go back to yam production (Timothy and Bassey, 2009), thereby increasing total tuber yield. The release of this package would be another milestone in the history of yam development in Nigeria.

Yam development through advances in soil management: Soil fertility is most crucial in the cultivation of yams in Nigeria and techniques on soil management for yam production have been developed for farmers. Awareness has been created on the role of organic manure on the yield of yam (Eze *et al.,* 2016). As a result of loss of agricultural land to erosion, landslide, and infrastructural development and other non-agricultural land transformation, there is no enough fertile land for producing the amount of yam that would be sufficient to feed the ever growing human population. Relying on bush fallow practices to restore soil fertility is no longer possible. Intense copping and over grazing without nutrient supplementation are other factors that affect yam productivity in Nigeria. Therefore Integrated nutrient management approach is developed to assist in yam production. This involves the combination of organic and inorganic fertilizer, coupled with soil conservation farming system in the supply of nutrients to crops. Results from researches conducted revealed the effectiveness of organic mineral fertilizer in giving higher crop yield compared with recommended NPK fertilizer alone (Eya, 2016). This indicated that efforts in this direction had built up soil productivity for yam and improves the quality of the soil on long term basis (Adeniyam and Ojeniyi, 2005). Compared with chemical fertilizers, integrated plant nutrition ensured longer residual effect and overall development of soil physical, chemical and biological qualities (Ayeni *et al.,* 2009) (Njoku *et al*., 2016).

In the year 2016, the yam breeding unit of the NRCRI Umudike began a series of evaluation of *Dioscorea rotundata* cv. Awada that performs very well in rocky soils and undulating environments. This yam variety has rotund tuber shape and would be ideal for mechanical harvesting with tractor drawn harvester. The release of this variety in the near future would go a long way to boost yam production using mechanical harvester.

Yam development through mechanization: Mechanical yam production in the field has not gone beyond using tractor to prepare the land for planting however, Minisett yam cutting machine was developed in 2016 by NRCRI Umudike pushing yam mechanization up to 5%. Breeding non-staking yam varieties with rotund tuber shape is still ongoing at the breeding unit of Yam Research Programme of NRCRI Umudike. Breeding mechanized yam crops is still on-going and is now a future prospectus at NRCRI Umudike.

Yam development through modern biotechnology: Biotechnology is the utilization of biological agents or their components for generating products or services for the welfare of mankind (Singh, 2016). Agricultural biotechnology comprises of molecular Genetics, Plant cell and Tissue culture which are major areas in modern plant biology. Conventional crop breeding is time consuming, capital and labour intensive. Techniques like molecular marker assisted breeding are required to shorten the period of breeding process by detecting promising lines based on a certain banding patterns of linked molecular marker. It is also rapid and accurate in the attempt to incorporate desired genes of agronomic traits from wild exotic species into food crops that lack them. Genetic engineering is another tool of molecular genetics which utilizes some species of the *Agrobacteria* to incorporate desired genes into food crops especially cereal crops. Transgenic cereal crops with resistance to herbicides and insect pests are in commercial use in most developed countries.

Another technique of modern biotechnology is plant cell and tissue culture. These techniques are used for the production of haploid plants through microspore culture, recovery of disease-free plant materials. The rapid development and selection of desired traits by cellular breeding, Hybrid rescue through embryo culture and micro propagation of elite genotypes and conservation of exotic germplasm.

Of all the dazzling speed and wonder techniques of modern biotechnology since its advent in the 1990's has not been exploited for the development of this African crop (yam). No yam genotype has been developed and released using biotechnology since its modern application in crop development. The Nigerian government should invest heavily toward the Training of specialists in the field of crop biotechnology to assist plant breeders for the development of the yam crop.

Yam development through production package

Over the years from the 1970's to date, agronomic research has been going on to release production packages which will enhance the yields and sustain the performance of the hybrid yam crop, the crop environment should also be improved. To achieve this objective, the following production packages developed include:

Land preparation**:** Deep cultivation for the development of tubers is necessary. Mounds may be used to reduce damage tubers by rats and ridges to reduce soil erosion on sloppy land or if mechanization is used. Stony soils must be avoided as they limit root expansion. Loose and well drained soils enable the roots to expand. In sloppy areas, ridges should be made across the contours to slow down speed of running rainwater, thus reduce soil erosion.

Seed rate**:** Mounds or ridges should be spaced 100cm by 100cm. one seed yam or cut sett weighing 250 -300g for ware tuber commercial yam production while spacing of 25cm by 25cm is for the planting of seed yam for seed yam production. One cut seed sett weighing 25g should be planted 25cm apart on top of the ridged seedbed, resulting in plant density of 10,000 plants per hectare for commercial ware yam production and 160,000 seed yam per hectare for seed yam production.

Planting: Planting should be done at time convenient to the farmer and when there is adequate moisture in the soil. This time usually corresponds between April and May each year. The seed yam /yam sett is buried 10cm deep into the mounds or ridges. Yam clones is usually planted in pure stands or intercropped with short maturing crops such as beans or groundnuts and can be planted on sides of mounds/ridges. Storage of tubers for a period of 3 months before planting induces sprouting and better establishment.

Field Management: Average soils do not require fertilizers. Compound fertilizers of Phosphorus and Potassium may be applied to increase yield where soil fertility is low. In the absence of local fertilizer, the following rates are suggested: N (34 - 45 Kg/ha), P_2O_2 (50Kg/ha -101Kg/ha), K_2O (84 - 169Kg/ha) or complete NPK 15:15:15 applied 400kg per hectare. Nitrogen fertilizers applied in large quantity are not recommended for tuber production because they increase vegetative production at the expense of tuber formation. Where there are no soil nutrient amendment measures.

Weeding: Weed promptly 2-3 times or as the need for weeding arises.

Harvesting: The yam clone plants matures 6-7 months after Planting (MAP) depending on the yam variety when the whole leaves have senescence or the leaves have dried up 100%. The tubers are dug up using sharp digging iron rod. The whole mounds/ridges are harvested and the tubers are sorted into ware tuber and seed yam and then stored in a well prepared barn. The yam tubers can be in the barn for up to 6 to 7 months from where they are selected for planting, eating or for marketing.

Pests: There are six major categories of pests that disturb yam plants in the field namely: Yam beetles, Crickets, termites, millipedes, vermin and rodents.

Yam beetles and Millipedes cause the most serious problems in the field because they destroy the tubers by boring holes. Damage is most serious in riverine areas. Crickets chew small shallow holes all over the tubers making them unsightly and unmarketable. Grasshoppers (*Zonozerus variegatus*) chew and destroy foliage of the crop. Damage can be serious during the dry season when high temperatures increase the growth rate of young stages of the grasshopper. Pests can be managed by applying integrated pest management (IPM) methods such as planting healthy tubers and planting a new crop away from old infested field, crop rotation and destruction of infested plant parts. A new crop should be planted in good time for it to mature and be harvested before the dry season. The crop should be weeded carefully and hill up base of plants and cover soil cracks where yam beetles, crickets and termites enter the tubers. The crop should be harvested as soon as it is matured. To reduce pest damage by physical destruction of larval stages, planting crop early for it to escape destruction during dry season and spraying contact insecticides when attack is high and/or a combination of the above are recommended. The method used for soil pests (Yam beetles, Crickets, termites, millipedes) control also controls a multitude of other soil pests and stem borers.

Vermin: Major vermin pests are bush fowl, land squirrel and wild pigs. To control damage by vermin, yam clones should be planted away from forests where the animals live. Crops can be planted in blocks and guarded against vermin and livestock by farming community. Main pests categorized under rodents are rats and squirrels. Rats attack yam clones which are usually weedy or are over mature. Management methods include cultural control methods like weeding the field and surrounding areas, harvesting crop as soon as it is mature, digging up and destroying nesting sites and trapping. Domestic cats can be useful in biological control option against rats at least in the yam barn.

Yam Diseases: Yam mosaic virus disease is caused by viruses. Symptom includes discoloration (yellowing) and distortion of leaves and stunting of plants. Viruses are spread by whiteflies and aphid vectors and planting infected tubers. Disease control is by planting resistant varieties and healthy tubers, destroying disease volunteer and host plants, crop rotation, roguing infected plants and planting barrier crops to intercept the flight of vectors.

Anthracnose: Symptoms include black lesions on leaves and stems often leading to plant death. Control of the disease is by planting resistant varieties and following good sanitation practices.

Prospects of yam production

Bassey and Nwankwo (2017) noted that there are many strategies of solving the major constraints in yam production in Nigeria. It involves a complex interaction of agronomic, genetic, technology, consumer preferences in the choice of species/cultivars and socio-economic considerations (Manyong *et al.,* 2001). The collaborative evaluation of 11TA derived breeding lines with the National Root Crops Research Institute, Umudike has resulted in the release of ten varieties of *D. rotundata* during the 2001-2009 research project in Nigeria. More lines have been released for multi-locational evaluation by the National Root Crop Research Institutes in Nigeria, with multiple pest and disease resistance, wide adaptability and good organoleptic attributes (NACGRAB, 2004). Attention has also been given to improved management practices, soil fertility management and development of improved production packages and development of simple and effective storage techniques (Katung *et al.,* 2006). In the year 2008, four more new hybrid yam varieties were released in Nigeria. These were made up of three water yam (*Dioscorea alata)* varieties and one white yam (*Dioscorea rotundata*) variety (Nwachukwu, 2009). The stages in yam breeding span over nine years which include hybrid botanic seed production (crossing), seeding evaluation, cloned evaluation, preliminary yield trial uniform yield trial, multi-location trial, national coordinated trial and on-farm pre-release trial. Similarly, the trial of 24 top yielding hybrid yam lines in Umudike and Utobi, resulted in the nomination of five yam lines (99/AMO/110, AMO/189, 99/AMO/115, 99/AMO/MAX and OO/AMO/191 for National Coordinated Research Project (NCRP) multi-locational trials based on their total fresh tuber yield rank sums (Nwachukwu., 2009). Seven varieties were released in the year 2016, which comprised of two hybrids and five registered landraces released as varieties for the first time in the history of yam releases in Nigeria. The National Root Crops Research Institute, Umudike has not lost focus in the pursuit of its official mandate. Aggressive efforts towards the realization of the highest yield possible have been intensified. Nevertheless, there are still constraints in yam production which research is striving hard to cover such as: lack of sufficient improved. diseases/pest resistant varieties, high cost of planting materials, post storage losses from infection, low multiplication ratio, high manual labour for weeding, fertilizer application, staking, harvesting and storage in barn.

Conclusion

Yam development has taken a long time to come by when compared with other crops as a result of the background of yam as African crop. The research on yam has been very gradual starting from 1923, speeded up in the late 1960 to 1970's and is continuing with the advent of biotechnology from the 1990's to date. Yams are an integral component of food consumption, agriculture and income in Nigeria. Despite the dazzling research effort, yam production in Nigeria is constrained by the high costs and limited availability of yam seed. Farmers save almost half of their yam harvests for next season's yam seed. Consequently, these households are not able to capitalize on the potential value of their harvests. Mechanical yam production in the field has not gone beyond using tractor to prepare the land for planting. Other field operations such as staking and harvesting which gulp the greater percentage of labour use in the field has not been solved. Biotechnological approach in yam development is still at the infancy. Relaxing the bottlenecks to production of yams will have great potential to increase the value of production, particularly for the poorest of farmers.

White yam (*D. rotundata* Poir) which is a prestigious and most preferred carbohydrate staple for peoples of the tropics particularly in West Africa and the Caribbean has not received much attention to yam development and research when compared with cereal crops. Yam production in these areas has been limited by constraints such as pests and diseases and poor food quality of some farmers' varieties. Most farmers do not have access to improved varieties. They depend still on unimproved cultivars that are low yielding and are susceptible to pests, diseases and other abiotic factors. Whenever farmers as a result of low yield, consume all what they have without reservation for replanting, the crop’s genetic base is gradually eroded. Also genetic variability erosion in yam easily occurs where there is no focus research on yams. Yam plants are well adapted to particular situations that other crops cannot withstand. Yam has its peculiar characteristics that make it difficult to obtain seeds and so when everything is consumed, the genetic variability is lost forever. Scientists have made some breakthroughs in conventional yam breeding yet more is needed to develop this crop to adapt to various soils, climates, pests and diseases, mechanization, farming systems of the people and acceptability by consumers. Fortunately, the problem of yam breeding through hybridization which seemed impossible to solve many years ago has now been put under control. Large collections of accessions with better flowering qualities are in the germplasm which could be manipulated to generate new varieties. Much has been done in yam development; however, more research is needed to give this African crop the first place in the world. Ameliorating the challenges facing yam research could be a giant step to improving livelihoods of resource-poor farming households in Nigeria. The research innovations are expected to drive down production costs thereby making yam growing attractive to farmers and increasing the supply of the commodity in the country. Conscious efforts should be put in place for yam research to produce adequate, good quality results for yam production.

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