

Novel Technologies for a Sustainable Seed Yam System

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The importance and promise of yam

Yam is one of the most important food crops in West Africa, where it is popularly known as the “King of Crops” because of its socio-cultural significance and economic value to the people of the region. In terms of production, the sub-region is second to none. West Africa accounts for 94% of global yam production (FAO 2021). Nigeria alone accounts for 67% of this production (50 million tons) and 74.6% of the total area planted (6.2 million ha).

➤ **69 million** tons are produced on
8.3 million hectares annually, mainly in five countries
Benin | Côte d'Ivoire
Ghana | Nigeria | Togo



The production value of yam exceeds the aggregate value of several major crops in West Africa, including grain legumes. According to the Food and Agriculture Organisation (Figure 1), the aggregate production value of yam is 29% more than cassava and 60% more than maize in West Africa (FAO 2018). Many irrefutable reasons support yam for sustainable food production in the region. Yam is also a versatile staple crop that addresses food and nutrition security. Although yam

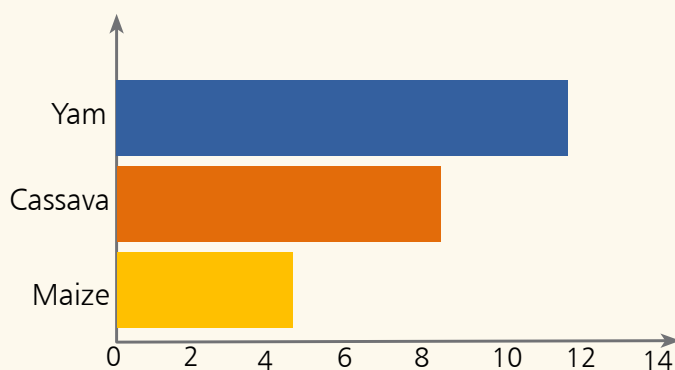


Figure 1. Production value (\$ Billions) of priority crops in West Africa (FAO 2018).

has an extended growing season, it is vital to the annual cycle of food availability due to the diverse agro-ecological adaptations and maturity periods. Therefore, consumers have access to yam all year round. Yam is nutritionally rich in proteins, vitamins C and A, zinc, iron, etc. It is a good source of energy, and 100 g of yam provides 118 calories. It is mainly composed of complex carbohydrates and soluble dietary fibre, which together raise blood sugar levels rather very slowly compared to simple sugar. Yam is therefore recommended as a low glycaemic index (GI) healthy food. Consequently, it has the potential to contribute significantly to ensuring the food and nutrition security of consumers. Despite the nutritional and economic importance of yam, its production faces many threats.

Yam production constraints

Many constraints mar yam production, and the foremost among them is the scarcity of high-quality seed yam of released varieties.



Figure 2. Yam pests and diseases that perpetuate with seed yam propagation (Figure source L. Kumar).

Traditionally, farmers recycle seed tubers by saving at least 30% of their produce to plant during the following cropping season. These seed tubers are often infested or contaminated with pests and pathogens such as nematodes, viruses, fungi, and bacteria that affect the quality of the seed and yields (Figure 2). Yam farmers have not yet been able to benefit from the advantages of using quality seed tubers due to a combination of factors, including:

- Low availability of quality seed yam.
- Low multiplication rates and inadequate technical know-how for mass production of early generation quality seed yam.
- Lack of private sector involvement in early generation seed yam production due to high production costs.
- Ineffective public sector production and distribution systems of early generation seed due to insufficient capacity and funding.
- Inadequate seed quality assurance systems.

These constraints formed the basis for various interventions in the yam seed system.

Novel technologies present new opportunities for the establishment of yam seed systems

To address the challenge of unavailability and farmers' inaccessibility to quality seed yam, the flagship project, Yam Improvement for Income and Food Security in West Africa (YIIFSWA) of the International Institute of Tropical Agriculture (IITA), has developed and validated tools and technologies to produce seed yam for the establishment of market-oriented seed systems that ensure the sustainable supply of quality seed yam in Ghana and Nigeria. Some notable research achievements include:

- Development of pathogen-elimination system using meristem tissue culture techniques combined with heat therapy. This method gets rid of viruses and endophytes from nucleus stock plantlets.



Conventional production

1 : 1-5 tubers

(depending on the variety)



Miniset Technique

1 : 15-30 setts

(depending on the size of the tubers)



Single node vine cutting (SNVC)

1: 120-300 vine cuttings

(depending on the System)

Figure 3. Multiplication ratio of various seed propagation technologies.

- The development of novel high ratio propagation technologies to produce early generation seed. Conventionally, yam has a low rate of multiplication of about 1:5 tubers per plant but with the development of technologies like the plantform temporary immersion bioreactor system, and drip system hydroponics in troughs or buckets and aeroponics system, the multiplication rate increases significantly to 1:50, 1:120 and 1:300, respectively (Figure 3). The high ratio propagation technologies for rapid multiplication of high-quality early generation seed are used to produce mother plants (breeder seed) for foundation seed yam production (Figure 4).
- The main objective of introducing the breeder mother plants in aeroponics system and drip system hydroponics is to generate single node vine cuttings for high-ratio propagation of clean planting materials, a critical milestone promoted to strengthen the capacity of the public and private sector partners in Nigeria and Ghana (Figure 5).
- The development of robust diagnostic tools for simple, sensitive, and quick detection of viruses in yam in the lab and field, i.e., multiplex RT-PCR, RT-LAMP, and RPA assays for the detection of yam mosaic virus (YMV) and yam mild mosaic virus (YMMV).



Figure 4. Breeder 1 seed production.



Figure 5. Breeder 2 seed production.

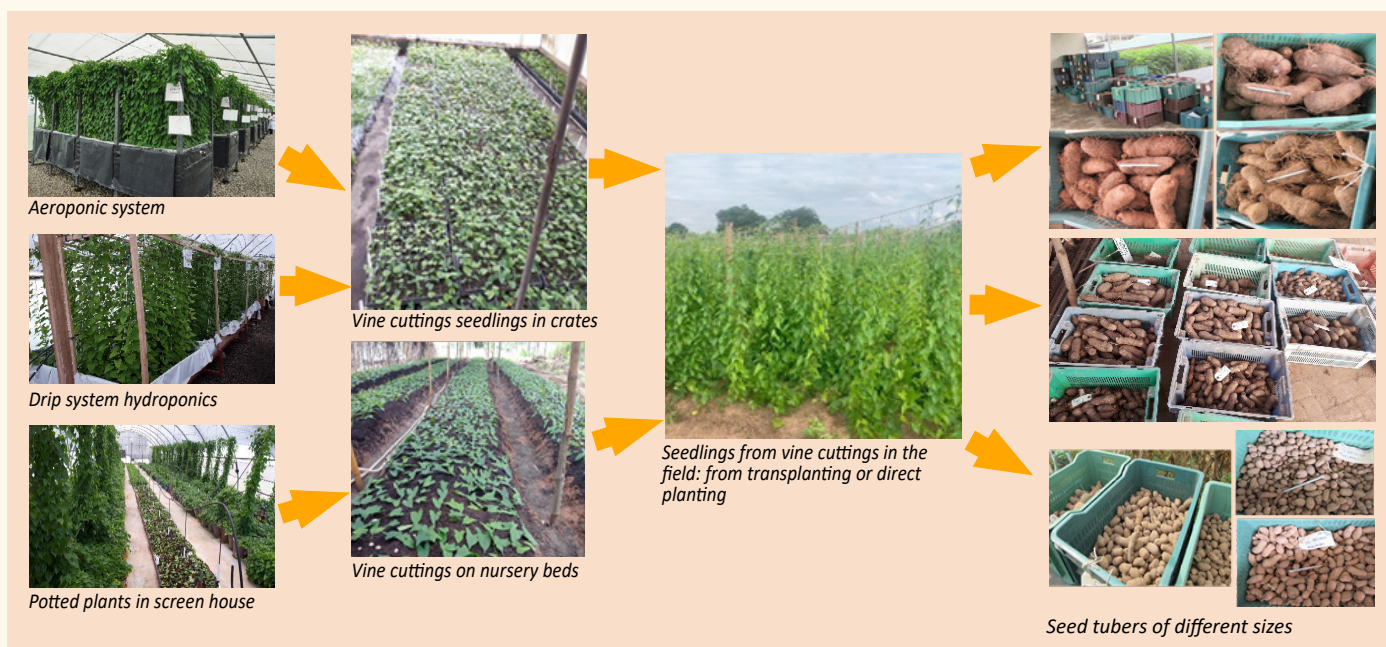


Figure 6. Foundation 1 seed production from breeder 2 seed.

- The development of quality management protocol (QMP) ensures the health, genetic purity, and physiological quality of various planting materials. Revised standards have been established for quality assurance and certification of early generation seed yam in Nigeria and Ghana.

Each technology (Figures 4, 5, and 6) has been strategically developed to increase seed multiplication and production rapidly, sanitarily, and economically for each of the three seed yam classes (breeder, foundation, and certified seeds). The combination of the technologies forms a formidable system (Figure 7) that accelerates early generation seed yam production for certified seed yam production.

By design, the seed production chain starts with selecting improved varieties released by the national variety release and registration committee of the country. The varieties are cleaned of virus by IITA and used to generate clean nucleus seed stocks through conventional tissue culture. The seed stocks are supplied to National Agricultural Research Institutes (NARIs), which use the temporary immersion bioreactor system to scale up the production of breeder seed and supply to private seed companies as progenitors for the rapid multiplication of

foundation seed. Private seed companies will use the aeroponics system and drip system hydroponics to generate high volumes of single node vine cuttings to produce foundation seed to supply seed entrepreneurs for certified seed production.

The certified seed producers, seed entrepreneurs, will sell seed tubers to ware yam farmers. In addition, all these production processes are monitored and evaluated based on the YIIFSWA yam quality management protocol, and seeds are tested using the diagnostic tools and tracking system by seed certification agencies to ensure seed health and varietal identity (purity).

Piloting sustainable formal seed systems in Ghana and Nigeria

After successfully developing and validating these technologies, the project successfully promoted and introduced the high ratio propagation technologies for seed yam production in Ghana and Nigeria.

The core of its success has been adoption of these technologies by public institutions and, most significantly, by the private seed actors. This has led to the achievement of the two key objectives of YIIFSWA, which are to develop a functional and sustainable seed system (Figure 7) that delivers

enough quantities of high-quality seed of improved varieties to farmers at the right time and at the right prices that encourage adoption; and to empower smallholder ware yam producers with the seed of improved varieties for increased productivity resulting in increased income.

So far, four national agricultural research institutes and eight private seed companies in Ghana and Nigeria have adopted the technologies. Together, these enterprising institutes and seed companies form the formal yam seed system in Ghana and Nigeria (Figure 8).

IITA has also successfully introduced a seed certification program that enhances the operational capacity, processes, and systems for enforcing the standards for certifying yam seed classes in Ghana and Nigeria. The National Agricultural Seed Council (NASC) in Nigeria and the Plant Protection and Regulatory Services Directorate (PPRSD) in Ghana, two agencies in charge of seed certification and seed industry regulations, were strengthened and equipped with quality diagnostic tools and facilities for seed certification, and information and communication technology tools for the digitalization of quality certification and assurance procedures using the Seed Tracker.

Public sector institutes and Certification agency (Ghana)	<ul style="list-style-type: none"> • Crop Research Institute (CSIR-CRI) • Savannah Agricultural Research Institute (CSIR- SARI) • Plant Protection and Regulatory Services Directorate (PPRSD)
Private Sector/ Seed Companies (Ghana)	<ul style="list-style-type: none"> • Iribov Ghana Ltd. • Fosuah Foods Ltd. • Hikma Agro Services Limited.
Public sector institutes and Certification agency (Nigeria)	<ul style="list-style-type: none"> • National Root Crop Research Institute (NRCRI)/Umudike Seeds • National Centre for Genetic Resources and Biotechnology (NACGRAB) • National Agricultural Seed Council (NASC)
Private Sector/ Seed Companies (Nigeria)	<ul style="list-style-type: none"> • Biocrops Biotechnology Limited • Da-Allgreen Seeds Ltd. • Nwabudo Agro Seeds and Inputs Company Limited • PS Nutraceuticals • Strategic Seeds Nigeria Limited

Figure 7. Public sector organizations and private sector seed company in yam seed system in Nigeria and Ghana.

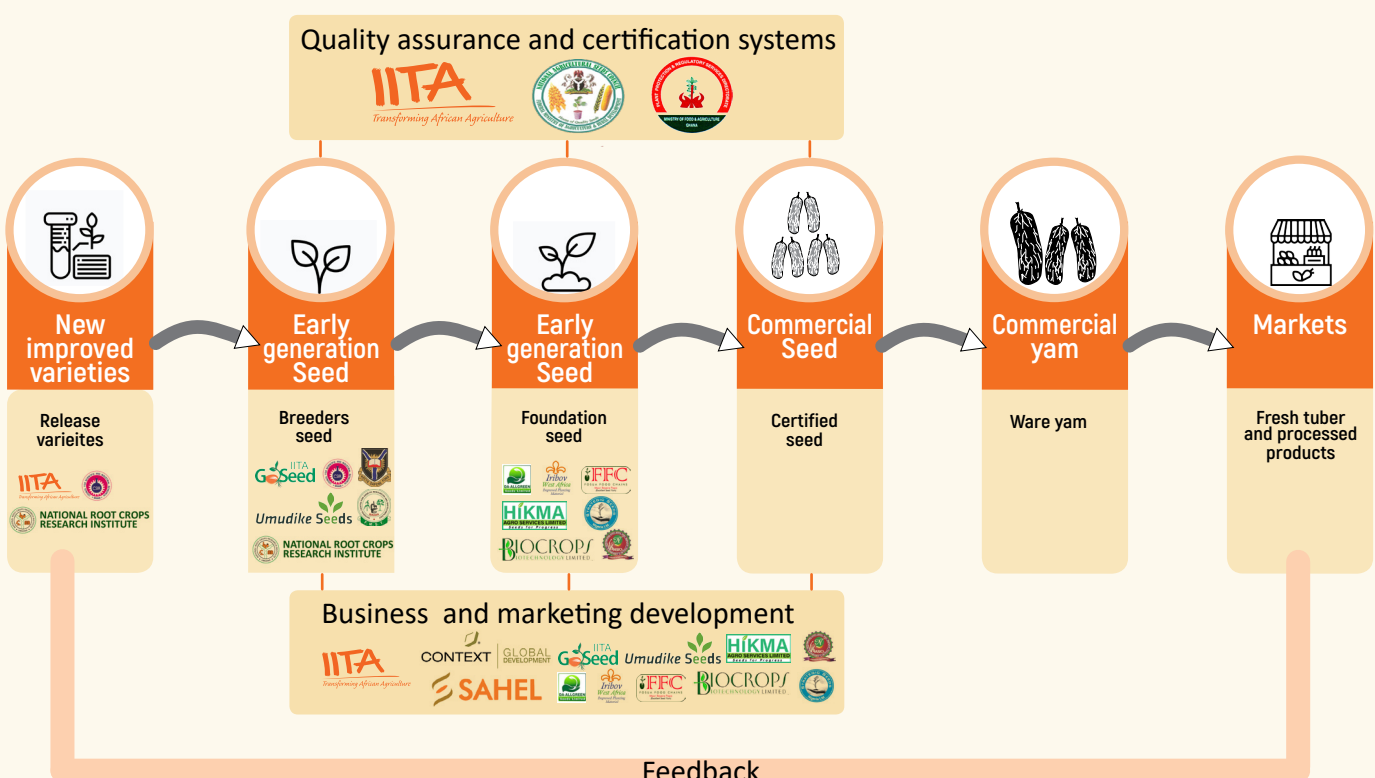


Figure 8. YIIFSWA-II seed system model.

The benefits of the YIIFSWA model

The sustainable supply of high-quality seed yam will improve the food security and income of farmers and other stakeholders in West Africa.



1 Increased yam productivity

The goal of the YIIFSWA seed model is to ensure the availability of improved, disease-free, and genetically pure seed tubers of market and farmer preferred varieties which will significantly boost yam production.

2 Reduced use of food tuber for seed

Establishing a formal seed system allows for the separate production of planting materials and ware yam. Farmers can purchase certified seed from their local seed yam entrepreneur or agro dealer.



3 Creation of employment and business opportunities for women and youth entrepreneurs to generate clean seed yam

The YIIFSWA seed model advocates and promotes the participation of women and youths in the system as seed entrepreneurs for certified seed production and marketing.

4 High ratio propagation of quality seed yam

Using high ratio propagation technologies is an efficient and profitable way of facilitating the multiplication and production of large quantities of clean seed tubers. This allows for the industry to cope with seed demands for released yam varieties.



5 Increased use of disease-free quality seed

In collaboration with the seed certification agencies such as the National Agricultural Seeds Council in Nigeria and Plant Protection and Regulatory Services Directorate in Ghana, the YIIFSWA project has designed a robust seed quality assurance system that ensures that only released and disease-free varieties are multiplied and passed on to farmers.



6 Improved distribution of genetic gains

The YIIFSWA-II approach can greatly reduce the time it takes for newly released varieties to reach farmer fields: from about five to ten years previously to immediate distribution after release.



Opportunities for replication and adaptation

The YIIFSWA seed system model for sustainable seed yam production has proven its effective viability in both Nigeria and Ghana. Eight private seed yam companies are currently multiplying their first commercial seed crops for commercial sale in the 2022 cropping season.

However, there is both a need and the opportunity to further strengthen these systems within Nigeria and Ghana and to replicate them in other West African countries that grow yam and seek to increase productivity of the crop. Governments and development partners seeking to replicate and adapt the YIIFSWA-high ratio seed system model should be prepared to do as follows.

1. Establish high ratio propagation facilities in the national agricultural research system to rapidly multiply early generation seed or planting materials of the markets' preferred,

promising, improved, and released yam varieties.

2. Establish an early generation seed business unit in a government entity, or in a private sector seed company, or both, with the responsibility to rapidly multiply early generation seed.
3. Nurture the creation of a network of seed entrepreneurs to support the early generation seed production. These are farmers who are trained and supported to multiply certified seed yam tubers profitably in their communities.
4. Strengthen the capacity of national regulatory authorities to carry out the necessary regulatory functions for quality assurance

The International Institute of Tropical Agriculture (IITA) and its partners under the YIIFSWA-II project are ready to help with similar project design, advice, and implementation.

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