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Foreword

Yams (*Dioscorea* spp.) are tropical tubers and are among the most important crops for food security and income generation in Africa, particularly in West Africa. More than 95% of global yam production (89 million tons) is concentrated in Africa, with Nigeria being the world's leading producer (62 million tons). Although yams have traditionally been used as a primary starchy staple food source, increasing urbanization in the major production zones has resulted in a growing commercial trade to supply urban markets. Lucrative opportunities have also emerged to supply West African diaspora communities in Europe and North America. These developments have provided significant opportunities for yam farmers. Still, major constraints such as pests/diseases, difficulty accessing agronomic advice, and poorly developed marketing infrastructure and channels have meant that average yields in Africa (8.4 t/ha) are well below the potential of more than 30t/ha. Arguably, farmers' difficulty acquiring high-quality seeds is even more critical. Farmers most commonly obtain yam seed by recycling from existing fields. Seed supply also occurs through informal markets. In both cases, however, yams selected for seed are typically smaller tubers, which are more likely to be infected by viruses or infested by nematodes. The consequent widespread usage of low-quality seed sustains low yields and prevents farmers from achieving their production potential. The limited supply of high-quality improved varieties exacerbates this problem. Although yam breeding is technically challenging, researchers have achieved significant recent success in developing improved high-yielding varieties in several of the major producer countries of West Africa. However, the absence of complete seed systems that provide a channel for delivering these varieties from breeders to farmers has hindered the speed of adoption. A key component of improved seed delivery mechanisms is the cost-effective rapid propagation of early-generation seed.

Researchers at IITA and in the national research systems of Ghana and Nigeria have worked with seed companies to try various approaches to address this challenge. These have included methods such as tissue culture, temporary immersion bioreactors, aeroponics, and semi-autotrophic hydroponics. Recent research has demonstrated, however, that one of the most straightforward approaches to rapid propagation – leaf-bud cuttings – is proving to be a preferred method for both researchers aiming to bulk up new varieties and private seed companies using the technique to produce large volumes of foundation and certified seed as minitubers in either confined or open field situations. The success of this approach has highlighted the importance of increasing awareness of the technique. This manual helps to address this by providing a detailed 'how to' description of the leaf-bud cutting technique. As such, it represents a valuable resource for all of those interested in the rapid propagation of yam seed, from researchers to seed producers, interested hobbyists, and gardeners. The manual is richly illustrated to ensure that users have a clear visual picture of each of the steps of the technique and associated aspects, such as structural requirements, media, agronomic measures, pests/diseases, and other potential challenges and constraints. The manual is the culmination of many years of research, and the methods presented here have been rigorously tested by research and private seed companies. Given the successes achieved, the manual is commended for application wherever convenient and rapid yam propagation methods are required. It is hoped that scaling the leaf-bud cutting approach will be pivotal in boosting the delivery of high-quality yam seed, thereby contributing to increased yields, improved incomes, and enhanced livelihoods of the millions of people who depend on the crop.

Dr. James Legg,
PROSSIVA Project Lead,
IITA Tanzania.
2025.

Acknowledgements

The authors are grateful to the Bill & Melinda Gates Foundation for funding the Yam Improvement for Income and Food Security in West Africa (YIIFSWA) projects (2011–2021) and the ongoing Program for Seed System Innovation for Vegetatively Propagated Crops (VPCs) in Africa (PROSSIVA), led by the International Institute of Tropical Agriculture (IITA) in collaboration with several public and private organizations to develop and scale innovations to modernize the yam seed system. This ensures the sustainable production of quality and healthy seed yams at an affordable cost. We acknowledge the contributions of all the YIIFSWA and PROSSIVA project partners in developing functional seed systems for yam in Nigeria and Ghana.

1

Introduction

The importance of yam

Yam is an important tuber crop in sub-Saharan Africa, particularly in the yam belt of West Africa, which runs from Côte d'Ivoire through Ghana, Togo, Benin, Nigeria, to Cameroon. Yam belongs to the genus *Dioscorea* and the family Dioscoreaceae. The major species cultivated for food include *D. rotundata*, *D. alata*, *D. cayenensis,* and *D. dumetorum*. Among these species, *D. rotundata* and *D. alata* are the most common and have high economic value. West Africa produces more than 95.6% of the world's yam, estimated at 88.3 million tons, with Nigeria producing about 69.3% (61.2 million tons) (FAOSTAT, 2024). The production value of yam in the major areas of cultivation in West Africa is much higher than that of other staple foods in the region. In Nigeria, for example, yam's production value is more than the combined value of cassava, maize, rice, millet, and sorghum. It is the food of choice for millions of people and contributes over 200 dietary calories daily for about 60 million people (Nweke, 2016; González Ramírez, 2019; Olabode, 2022).

As a food security crop, yam has a longer shelf life than other root and tuber crops. After harvest, tubers can be stored from one season to another, usually under rudimentary and traditional storage conditions. When tubers are planted, they can withstand the delayed or irregular rainfall that generally characterizes the beginning of cropping seasons better than many other crops. The sociocultural importance of yam is worthy of note, as it is linked to various religious and cultural ceremonies across the yam belt. Despite the importance of yam as a food crop and cultural item, the increase in its productivity and the development of some components of its value chain have been very slow or absent. The area under yam production has continued to increase much faster than its yields (Fig. 1). This challenging situation indicates that more inputs, such as labor, fertilizers, quality seed, and land, are required to meet the growing demand for yam.

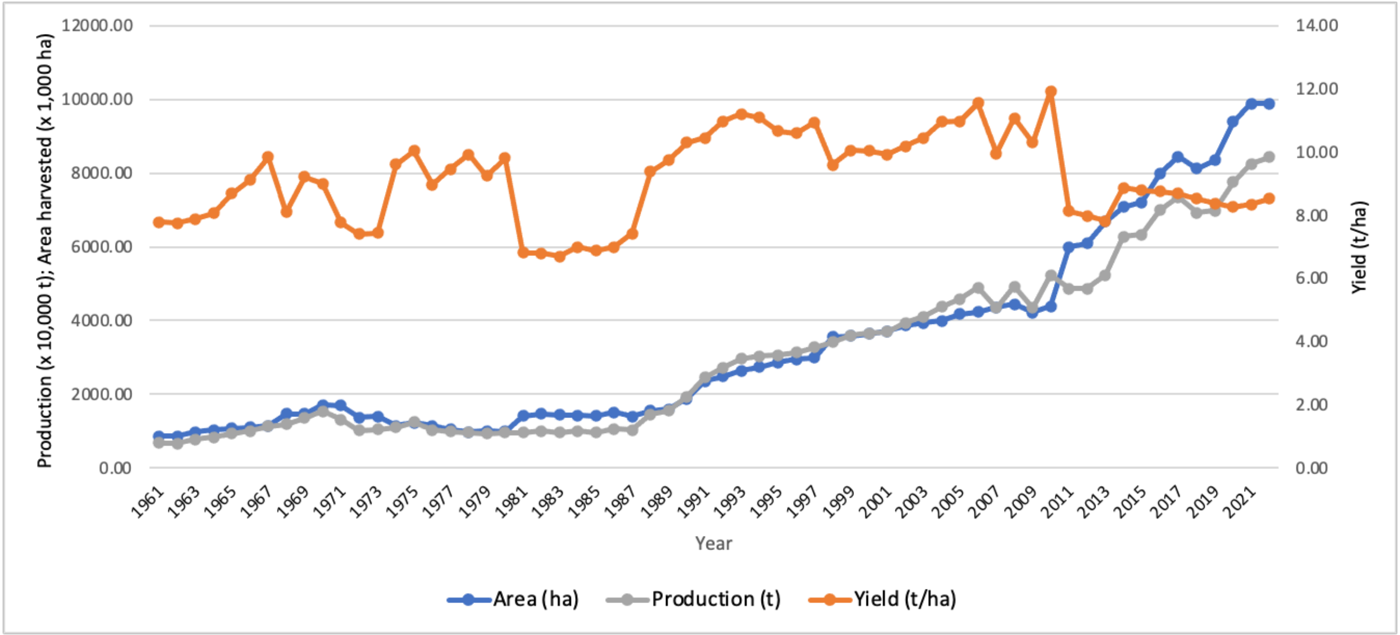

Figure 1: Trends in yam production and yields in West Africa, 1961–2021.
Source: **FAO database (2024).**

Seed: A significant challenge in yam production

Among the significant challenges contributing to limited yam productivity, the traditional mode of propagation using large tubers or pieces of tubers is crucial. The seed multiplication rate of traditional propagation methods is low; hence, there is limited availability of quality planting materials. Most seed stocks in use are contaminated with viruses, especially the yam mosaic virus (YMV) responsible for about a 40% reduction in tuber yield (Nkere et al., 2018). In the past few years, thousands of yam farming households have lost their yam planting materials (tubers) due to communal clashes, such as in the Middle Belt of Nigeria, which is a major producing zone, or the unpredictable weather conditions in the northern limits of yam growing zones (Ajayi et al., 2020). The high cost of seed yam, which is 30–50% of the total cost of production, often prevents yam farmers from replacing planting materials whenever conditions become conducive for farming (Nwike & Ugwumba, 2016). Also, the 200– 1000 g tubers used traditionally as planting materials are suitable for food. The tubers of 1000–1500 g are preferred in the yam export trade for food, but farmers preserve most tubers of this size to propagate the crop (Danquah et al., 2018). The traditional seed tubers are bulky, and transportation is expensive (Figs. 2 and 3).

Figure 2: Large yam tuber pieces (200–500 g) used as planting material in traditional production.

Figure 3: A truckload of seed yam to plant about 1 ha.

Conventional methods of yam propagation

Yam has a vegetative system comprising fibrous roots, twining stems (vines) with branches and a foliar apparatus. The plant produces underground tubers, and in some species, tuberized formations known as bulbils are formed at the leaf axis. The sexual reproductive system includes flowers, fruit, and seed which are mostly used for breeding purposes.

Conventionally, yam is grown as a calendar crop following the rainfall pattern of the locality for 7– 9 months. However, as a perennial crop, its growth can be manipulated into several annual productions. The agronomic operations usually carried out in the field during production include land preparation, planting, staking, weeding, and harvesting.

Customarily, saved tubers from one harvest are used to propagate yam in a subsequent production season. In traditional systems, tubers are cut into large chunks of 200–1000 g, or whole tubers of similar size are planted, resulting in multiplication rates of 1:3 to 1:10. These rates are much lower than cereal crop multiplication rates (1:300) (Aighewi et al., 2021). The large tuber portions are typically planted to produce table yams, and at harvest, tubers of 200–1000 g are reserved as seed to grow the next crop. In this system, many farmers practice double harvesting for early maturing varieties. This practice is sometimes referred to as “milking”. Tubers from the first harvest done six to seven months after planting are used for food, and those from the second harvest after senescence at the end of the season are mainly used as seeds for the next crop.

Climate change and yam seed security

The changing climatic patterns observed in recent years affect seed availability for yam farmers who depend almost entirely on rainfall for production. When the duration of the rainy season becomes limited by a late start or early cessation of rains, the second harvest of the yam crop destined for seed will reduce. If the rains cease shortly after the first harvest, the yam foliage will senesce with only a limited bulking of the seed component of the total harvest. Without a reliable source of quality seed, yam farmers often recycle most of their seed for several generations and can rarely replace it entirely. The accumulation of pests(nematodes, scale insects and mealybugs) and pathogens(viruses, fungi and bacteria) in recycled seed also reduces yields. The high cost of seed, low tuber multiplication rate, and seed yields result in seed and food insecurity and loss of an essential source of income.

Why this publication?

Yam is a traditional crop in West Africa. Still, it has yet to receive the magnitude of research support it deserves, especially in developing its seed systems in many countries in West Africa, where the crop is a significant source of food and income. Researchers of the National Root Crops Research Institute (NRCRI), Umudike, Nigeria and the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, made limited efforts in the 1980s to improve yam's tuber-based propagation methods, resulting in the minisett technique using 25 g setts (minisetts) for seed production (Aighewi et al., 2014). The minisett technique helped to develop some seed yam enterprises in Nigeria along the banks of River Niger, mostly around Illushi, Otuocha, and Idah. Specialized seed yam farmers in this region produce to feed a vibrant seed yam market in Illushi, Edo State.

The YIIFSWA project of IITA, which operated for a decade between 2011 and 2021, studied and better understood the limitations of clean seed yam production. The project developed novel, high-ratio propagation techniques for yam, quality assurance procedures, and methods for seed health testing and management. They developed the capacity of national program partners as well as the public sector, and they worked with policymakers to create an enabling environment for establishing a sustainable formal seed yam system with the involvement of private entrepreneurs in early generation seed (EGS) production (Maroya et al., 2017; Balogun et al., 2017). Another initiative, PROSSIVA, also led by IITA, was initiated in 2022 and is conducting research to deliver innovations that resolve bottlenecks at specific stages across the yam seed value chain to improve the multiplication rate of quality seed yam production.

Farmers and researchers are familiar with planting large pieces or whole tubers of 200 to 1500 g directly in the field to produce ware yam. Researchers attempted to use vine cuttings in the past but had poor success rates even with hormones, and plants that emerged had a prolonged juvenile stage (Aighewi, 1998). However, recent research has developed innovative methods to rapidly multiply yams using vine cuttings and minitubers of less than 10 g in size. Up to 96% success in vine-cutting establishment has been achieved by the above seed projects without the use of hormones. This new knowledge requires the development of capacities to manage the new types of yam planting material. Producing mother plants in the screenhouse, making leaf-bud cuttings (LBCs) and rooting them before transplanting or planting directly in the field are unfamiliar methods of yam production. The size of viable seed tubers could be as small as a pea, some weighing less than one gram. So, handling these materials could significantly challenge the average yam producer.

With the new knowledge gained from research, there is a need to redefine the concept of seed yam quality, especially with the emergence of the formal yam seed system. Developing more yam seed enterprises is advocated to satisfy high seed demands and rapidly multiply and disseminate released improved varieties. Hence, knowledge of the essential nursery practices for seed production for a successful modern yam seed enterprise is indispensable. Success using the production techniques described in this publication further adds value to an already high-value crop. The information presented in this document will also make it possible for seed yam to be produced in areas where yam production is declining due to climate change. Yam producers in areas where the rainy season has become too short can benefit from the information presented in this publication by focusing on seed production, which requires a shorter season than ware yam. Also, seed yam could be produced in nontraditional, yam- producing areas with a shorter rainy season of about six months or less.

The practices described in this manual will help the high-ratio propagation of virus-free yam planting materials devoid of soilborne pests, especially nematodes. Readily available substrates are used to produce quality seeds within the screenhouse or nursery. Innovative methods increase the production of quality seed yams per unit of time and space compared to traditional production methods.

This publication advocates seed yam production as a separate venture from ware yam production to adhere to quality specifications. It aims to induce the creation of more business opportunities in the yam value chain and ensure a more sustainable supply of planting materials even during unpredictable environmental conditions. The production and use of quality seed yams, particularly in the formal seed system, will increase the availability and adoption of improved yam varieties within the shortest time possible.

Although more published work is needed on the agronomy of producing seed yam using vine cuttings, the overall requirements for yam cultivation can guide us. At the same time, a compilation of the much-needed information on suitable agronomic packages for this new propagation system is ongoing. Seed entrepreneurs, researchers, farmers, and amateur yam producers will all benefit from this document.

2

The benefits and challenges of using vine cuttings for yam propagation

Benefits of using vine cuttings for yam propagation

A significant advantage of using vine cuttings to propagate yam is to save more tuber yield for food and increase the economic value of the crop. The yam tubers used as food could be as little as 50 g or less and as much as 25 kg or more. However, since part of the harvest of a ware yam crop is typically preserved to plant the next crop, small tubers of 200–1500 g are set aside as seed. Some farmers leave tubers of less than 100 g in the field, while others take them home to be roasted or boiled for food, indicating that almost the entire harvest can serve as food. If vine cuttings are used instead of the average 250 g seed as in traditional systems, farmers will save 2.5 t/ha of seed for consumption. So, using yam foliage, generally considered "noneconomic," for propagation will further add value to the crop. Other benefits of using vine cuttings include:

- The multiplication ratio is high (1:300 for vines compared to 1:3 for tubers), making it possible to produce high-quality seeds of improved yam varieties for large-scale distribution.
- The high multiplication rate could significantly reduce the unit cost of yam planting materials.
- Initial tuber-borne diseases and pests are avoided, especially parasitic nematodes that are often transferred to the tuber from the soil.
- Plants obtained are uniform in terms of age and establishment.

Challenges that may be associated with the use of vine cuttings

- Systemic pathogens, such as viruses, can spread along with the multiplication of plant tissues. Therefore, users must use virus-free planting materials as mother stocks.
- Vine cuttings are more delicate to handle as planting material, and compared to tubers, only short-term storage is possible.
- The availability and maintenance of suitable and affordable propagation/growth media or soil for large-scale production could be a problem in some locations.

3

The requirements for establishing a yam vine propagation facility

A significant requirement for establishing yam multiplication using LBCs is a screenhouse for producing the mother plants. Plants produced in the screenhouse are more robust and less fibrous than those from the field. The mother plants must be healthy and well-nourished for the LBCs to have a high rooting percentage. Using healthy planting materials in an aphid-proof screenhouse ensures that the mother plants stay healthy. The structure and size of the screenhouse are variable depending on the producer's needs. Other necessary materials include containers for planting, which must have holes at the bottom for good drainage, substrates, basins, or buckets to hold chemicals for treatment, water, vines, and LBCs. Sharp cutting implements, such as knives and scissors, are also required, as well as a means of delivering water, such as a watering hose, can, or drip irrigation. Some available substrates are described below due to their importance in the growth and development of the mother plants and LBCs.

Substrates for rooting LBCs and producing minitubers in the screenhouse

In the screenhouse, yam plants can be grown in soil or substitutes made with plant organic materials (referred to as soilless media). The soilless culture could have natural organic substrates such as cocopeat, peat, or rice husk. These absorb and retain moisture well but must be fortified with the nutrients needed for plant growth and development. Some substrates may have limited quantities of nutrients that are quickly depleted. Figure 4 shows plants of the same variety and age growing in different media and exhibiting different deficiency symptoms. Hence, seedlings must be watered with a diluted fertilizer solution that supplies all their nutritional needs soon after they emerge. Inert substrates such as sand may be used in soilless culture. soilless culture. The inert material does not add or alter the plant nutrient level in any way. Hence, all the nutrients needed for plant growth and development are supplied as a solution in irrigation water (fertigation). Different solid substrates have merits and demerits and could be used alone or in combination with varied ratios. Seed yam producers can assess locally available substrates to determine their suitability for root yam cuttings and producing tubers. A suitable growing medium should be fine, uniform, and loose and have both an excellent water holding capacity and the ability to drain adequately for good aeration of the roots.

Figure 4: Leaf-bud cuttings of the same variety and age growing in different substrates

Cocopeat

Cocopeat is a by-product of processing coconut husks, known as coir dust, cocopeat, coir pith, or simply coir. It is widely used or combined with other substrates in horticultural production. Where readily available and affordable, cocopeat (Fig. 5) is a good growing medium component for seed yam production. It has pores that facilitate the exchange of air and the entry of sunlight and can hold 8–9 times its weight in water. The high water holding capacity of the medium may cause a poor air–water relationship, leading to low aeration within the medium and poor oxygen diffusion to plant roots. When applying water, take note of this property of cocopeat. An advantage of using cocopeat is that it can be reused for up to 4 years (Gohil, 2018).

Figure 5: 1. A block of cocopeat and 2. the prepared substrate used to plant leaf-bud cuttings.

Rice husk

Rice husk is generated during the milling of rice grain. The high silica and lignin (22.5%) content of rice husks make them insoluble in water, tough, woody, and abrasive, with low nutritive properties and resistance to weathering (Daifullah et al., 2003; Ghosh, 2013; Rosado et al., 2021). For some rice millers in Nigeria, the husk is not of commercial interest, while others sell it as animal feed. Presently, heaps of rice husks continue to rise at some milling sites where they are either burned or just dumped as waste (Fig. 6).

Figure 6: 1. Rice husk dump site in Abakaliki, Ebonyi State, Nigeria (Picture Source: D. Aihebhoria). 2. Fermented rice husk ready for use.

Various techniques, such as soaking in hot water, irradiation, acid and alkaline hydrolysis, ensiling, fermentation, and using enzymes and antibiotics, have been suggested to make rice husks usable (Aderolu et al., 2007). The rice husks are fermented or carbonized before use to root yam LBCs and produce minitubers.

Fermentation of rice husk

The simple process of fermentation transforms rice husk into a suitable substrate for rooting yam LBCs and producing minitubers. The husk collected from dumps is soaked with water and packed into heaps for fermentation. The temperature within the heap increases rapidly, reaching about 68 °C before dropping to 24 °C (Fig. 7). This process takes about three weeks. The rice husk is then used as substrate in hydroponic systems or combined with sterilized topsoil in a ratio of 1:1 for vine and tuber production. Fermented rice husk has a good water-holding capacity.

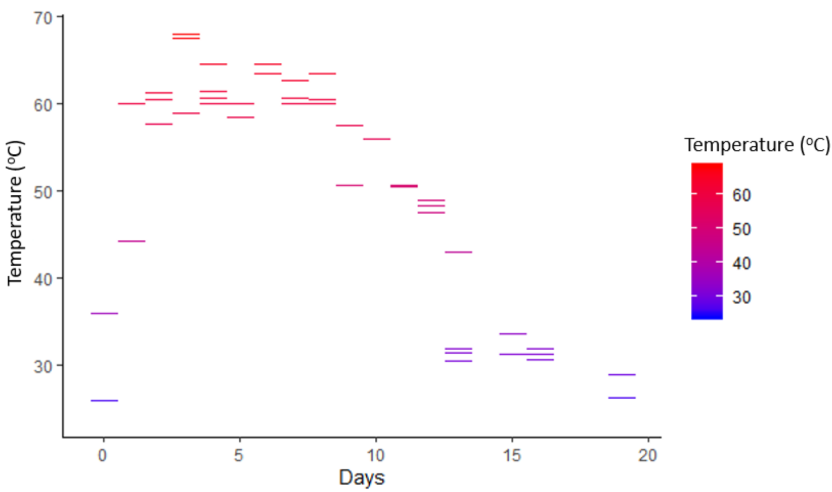

Figure 7: Heat map showing the rise and fall of temperature (°C) during the fermentation of rice husk.

Carbonized rice husk

Due to growing environmental concerns and the need to conserve energy and resources, efforts are made to burn the husks under controlled conditions to utilize the biochar or residual ash (Fig. 8) in several ways. To carbonize rice husk, pour and spread it around a carbonizer (a metal drum with both ends open) to cover the entire body. Make a fire with wood inside the carbonizer. When the rice husk on the surface starts to turn black, mix it with a shovel until all of it turns black. Remove the carbonizer and sprinkle the burnt husk with water to put out the fire. Spread it out to cool before use or pack into bags and store. To obtain ash, the husk is allowed to burn completely. The products of thermal degradation of rice husks are used in hydroponic systems or combined with other media for vine rooting or yam minituber production.

Figure 8: 1. Biochar. 2. Filling nursery bags with rice husk ash for planting leaf-bud cuttings.

Sand

Sand drains very quickly, and its moisture-holding capacity is poor. Sand needs the nutrients required for yam production. However, it has been used successfully for seed yam production in the screenhouse. Sand obtained from a riverbed was sieved, soaked for 10 minutes in 10% sodium hypochlorite (household bleach), and rinsed thoroughly to remove the chlorine. It was left overnight on a raised metallic frame to drip off and for any chlorine residues to evaporate (Wanjala et al., 2020) before use. The nutrient solution in Table 1 was applied to sand to produce seed yam.

Soil

Various soil mixtures can be used as propagation substrates. Soil mixtures are prepared by mixing sand, loamy soils, and manure in various proportions depending on the soil texture. Good topsoil should be used. The ideal soil mixture should be porous and have good water-holding capacity. It is good to sieve stones, gravel, big soil clods, pieces of sticks, etc., before mixing the soil.

In conventional practices, sterilized, soil-based substrates are used. Sterilization will eliminate soilborne microbes, pests, and weed seeds. However, sterilizing soil is labor-intensive, time-consuming, and expensive. A small-scale producer can treat a small quantity of soil mixture by placing slightly moist soil in a heat-resistant container in an oven set at about 100 °C. The mix must reach a temperature of about 82 °C for at least ½ an hour. Avoid overheating, as this can damage the soil. This treatment should kill several plant pathogens and eliminate potential plant pests and weed seeds. Garden soil may be too heavy by itself and have poor drainage. Hence, there is a need to mix it with other substrates.

Containers and structures for planting LBCs

Various types of containers are available commercially for planting cuttings (Fig. 9). Individual pots or strips of connected pots of different shapes and sizes exist. The seed producer may even fabricate containers to meet a specific requirement. The container selected should be economical and durable, space saving, have drainage holes in the bottom, and be deep enough to hold an adequate volume of growth medium. The type and size of the container will depend on the size of tubers desired: small containers for small tubers and large containers for larger tubers. Standard pots are good, but they need more space. Where the connected seed pots are small, planting in alternate pots on the sheet will prevent overcrowding of the cuttings (Fig. 9.1), which hinders adequate watering of the cuttings.

Figure 9: LBCs planted and growing in different containers: 1. Connected seed pots (flats); 2. Folded plastic sheets; 3. Crates; 4. Nursery bags; 5. Wooden boxes lined with plastic sheets fixed to a metal frame; 6. Nursery pots.

Vertical planting of minitubers or LBCs is possible for more efficient use of screenhouse space. Arrange the containers used for planting on layered stands (Fig. 10), ensuring adequate exposure of all plants to light. Yield from sections of the vertical stand that do not receive sufficient light (e.g., the lowest level in Fig. 10.1) will be low. Low-cost materials such as bamboo have served as containers to produce minitubers (Fig. 10.1).

Figure 10: Vertical planting in 1. Slit bamboo on a triangular stand; 2. Seed trays on a metal stand; 3. Slit PVC pipes on a metal stand.

4

Sourcing, production, and maintenance of mother plants

Sourcing of planting materials and establishing mother plants

The planting materials for mother plants are obtainable from several sources, namely, hardened plantlets grown in temporary immersion bioreactors (TIBs), aeroponic or semi-autotrophic hydroponic (SAH) systems, and hardened plantlets from LBCs or unrooted LBCs, as well as sprouted minitubers (Fig. 11). Make sure that the stock plants used for sourcing planting materials are free of viruses (clean plants), especially yam mosaic virus (YMV) and yam mild mosaic virus. Clean planting materials will ensure optimum productivity and control the spread of viruses in the screenhouse, nursery, or open field. All the factors that affect yam performance in the field also affect plants in the screenhouse or nursery.

Figure 11: Different planting materials used to start a mother garden for vine production: 1. Hardened plantlets from TIBs; 2. Plantlets from LBCs; 3. Freshly cut LBC; 4. Sprouted minitubers.

The LBCs, plantlets, or minitubers are planted in diverse substrates and containers in a screenhouse and nurtured by providing adequate water and nutrients until the mother plants are due for cutting. Where possible, stake the mother plants to optimize the exposure of leaves to light, enhance growth, and facilitate vine harvest (Fig. 12). Mother plants are produced in the screenhouse because it has been established that the cuttings obtained from such plants root better than those from field plants (Okunade et al., 2014).

Figure 12: Mother garden with disease-free plants in the screenhouse.

Nutrient supply to mother plants in the screenhouse

Customarily, soil is the medium in which plants grow. It provides support and the minerals needed for growth and development. With adequate moisture in the soil, the minerals are dissolved and absorbed by the roots. When plants are grown in other media such as cocopeat, rice husk, peat or various composite mixes, the required nutrients may be available in insufficient quantities. The producer must plan to supply all the necessary nutrients, especially if an inert substrate such as sand is used. Nutrient solutions used in soilless culture must have adequate macronutrients and micronutrients. The formulation should consider the plant's needs at different stages of growth, the environment (light intensity and temperature), and the type of soilless culture system. Table 1 shows an example of fertilizer composition for soilless propagation using rice husk, cocopeat, or sand as substrates and applied fortnightly.

The nutrition of mother plants plays a significant role in the development of roots and shoots of cuttings taken from them. Generally, low to medium levels of nitrogen result in a higher percentage of rooting than high levels, and extreme deficiency of N lowers rooting. Avoid the application of N fertilizer close to the time of taking cuttings, and plants should grow in full light to accumulate carbohydrates for better establishment of cuttings.

Table 1: Nutrient composition (in 800 liters of water) to fertigate yam plants for vine production in the screenhouse.

S/N	Nutrient	Quantity (grams)
1	Ammonium nitrate - NH_4NO_3	32
2	Potassium sulphate - K_2SO_4	223
3	Triple super phosphate - TSP	47
4	Potassium phosphate - $KH2PO_4$	158
5	Magnesium sulphate - $MgSO_4$	50
6	Calcium nitrate - $Ca(NO_3)_2$	189
7	Potassium nitrate - KNO_3	186
8	Terratige chelate (micronutrient)	10

Balogun et al., 2021

Table 2 depicts the fertilizer regime for a composite substrate of topsoil and fermented rice husk (1:1) using NPK 15-15-15 in pots in the screenhouse. Each pot contains 15 kg of substrate and two plants. So, each plant receives about 27 g of fertilizer during a 32-week period.

Table 2. Fertilizer application schedule for mother plants in the screenhouse.

Time of application (WAP)*	Quantity (g/plant)	Notes
4	9	Applied to the substrate after plant establishment
10	4.5	Applied two weeks before the first vine harvest
13	4.5	Applied one week after the first harvest of vines
19	4.5	Applied one week after the second vine harvest
25	4.5	Applied one week after the third vine harvest

*WAP = Weeks after planting the source plants.

The time of fertilizer application is vital in determining foliage growth and yield. Too frequent supply and high concentrations of nutrient solutions will cause nutrient toxicity and inhibit growth. Low frequency of nutrient supply will cause nutrient deficiency and low yield of foliage or tubers. Producers can investigate other fertilizer application options for different substrates and vine harvest regimes. Apply the fertilizer a few centimeters away from the plant to prevent scorching.

5

Harvesting vines from mother plants and preparing LBCs

Harvesting vines

The time to take cuttings from the mother plant depends on factors such as the variety (speed of early vegetative growth), the business strategy of the seed producer, environmental factors, and management of the mother plants. It is also dependent on whether the producer wants to obtain juvenile vines to produce full-grown plants to generate vine cuttings or matured vines for fast minituber production. Pruning between 8 and 16 WAP (about ten weeks after emergence) will give mostly juvenile shoots, while physiologically older vines are obtained after this period when tuberization would have commenced. Vine harvest is as follows:

1. Water plants adequately a day before the scheduled harvest of vines to keep them turgid.
2. Cut the vines from the mother plants with a sharp implement, leaving two or three nodes above the soil or substrate level. The buds at the nodes of the vine stub will produce new shoots for later harvest or be allowed to grow fully to enhance tuber production (Fig. 13).
3. Place the cut vine into a container of water to prevent dehydration (Fig. 14.1).

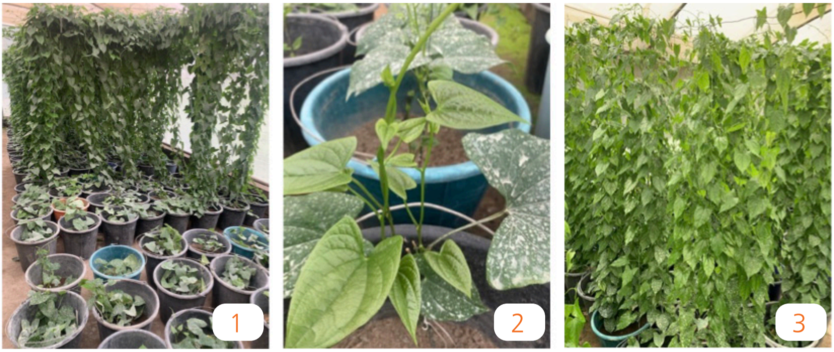

Figure 13: 1. Mother plants that are partially harvested of vines; 2. Plant with regrowth after cutting vines; 3. Regrowth of foliage after eight weeks.

To have more cuttings, a seed producer may wait for a large canopy to develop before harvesting vines. However, the earlier the vines are harvested, the fewer LBCs obtainable, and the faster new shoots will be produced. The number of nodes per plant determines the number of LBCs obtainable. The number of times to prune mother plants depends on the crop management regime. At IITA Abuja Station, three vine harvests are usually made before the mother plants are forced to senesce by stopping water application. This plan allows time for cleaning and preparing the screenhouse for the next LBC production cycle.

Preparing leaf-bud cuttings from yam vines

A sharp pair of scissors, razor blades, or a knife are needed to take cuttings. To prevent the transmission of diseases, make cuttings under hygienic conditions, and preferably, dip the cutting implements in 60–70% ethanol or one part of household bleach to nine parts of water. While handling the cuttings, avoid damage to the bud or growing point of the cutting where physiological activities take place, leading to root and shoot formation. Follow the steps below to prepare leaf-bud cuttings.

- In a container, mix 2 g of broad-spectrum fungicide, Mancozeb (80% WP), in 1 liter of water and mix well.
- Remove the previously cut vine from the water (see the previous section) and make a clean cut through the stem at an angle. Each cutting should contain one node with a bud, one leaf, and about

1 cm stem piece on either side of the node (Fig. 14.2). While cutting, detangle the vines and leaves carefully to avoid leaf loss. A high leaf loss level is usually inevitable for vines from unstaked plants

- Dip the LBCs in the fungicide dip for 10 minutes (Fig. 14.3). [Caution: Users should ensure basic personal safety, such as the use of plastic gloves and nose mask, during steps involving fungicides.]
- The cuttings are ready to be planted in the propagation medium in containers in the screenhouse or on beds in the field. After the fungicide dip, plant the cuttings as soon as possible.

Figure 14: Making LBCs. 1. Whole vine length steeped in clean water; 2. Single-leafed LBC cut from the vine; 3. LBCs in fungicide solution.

The yam vine's phyllotaxy usually has alternate and opposite leaf patterns on the same plant. In the opposite-leaved section, the leaves are paired at a node and borne opposite each other (Fig. 15a). After making LBCs in this section, the LBC may be planted with both leaves or with one leaf detached. However, where there is a need to increase the number of nodal cuttings rapidly, the piece of the stem can be split lengthwise to have two cuttings, with each piece having its node intact. Each piece grows into a standard plant if well treated in the fungicide solution before planting. Where there is an axillary shoot at the node (Fig. 15b), plant the LBC with the shoot. If the cuttings are obtained from a young mother plant, the shoot will continue to grow after rooting. However, if the mother plants were older and already tuberizing, the leaves of the axillary shoot would only get bigger and thicker.

Figure 15: Opposite-leafed LBC (a); LBC with axillary shoot (b).

The multiplication rate of a well-nurtured mother plant is high. Well-maintained mother plants of yam varieties Kpamyo and Asiedu grown in the screenhouse for up to 12 weeks produced an average of 182 LBCs at the first cutting. Regrowth from the same plants averaged 118 LBCs after eight weeks. The same mother plants gave an average of 60 LBCs during a third batch of vine harvest. Thus, 360 LBCs, and possibly more, could be derived from individual plants in one production cycle of 28 to 32 weeks.

Factors affecting the rooting, establishment, and development of LBCs

Several factors affect the successful rooting of cuttings, such as the health and nutritional status of the mother plants. Cuttings from healthy, well-nourished plants growing in adequate light are more successful in rooting than those from malnourished plants. Also, the position of the LBC on the mother plant affects growth and development. Cuttings from the most mature part of the plant are more fibrous, while those from the tips are too young and succulent and may not root fast. The mid portions of the vines give better cuttings. The physiological age of the mother plant significantly determines the response of the cuttings obtained from it. Cuttings taken from a juvenile mother plant in the active vegetative phase will grow into a complete plant (Fig. 16.1 & 16.2), having a root system, extended vines with leaves, and tubers. From the planting of LBCs to maturity of seed tubers, it may take up to five months, and tubers can weigh more than 250 g, depending on the production factors. However, LBCs derived from older mother plants active in tuberization will mostly produce only roots and tubers (Fig. 16.3). For plants that do not develop shoots, minitubers would mature in about three months and weigh less than 10 g, with most tubers in the 2–6 g range. These tubers are good for producing mother plants in the screenhouse or seed yams in the field.

Figure 16: LBC producing a shoot (1) will grow into a full plant (2); LBC from a physiologically mature plant will produce roots and tubers without a shoot (3).

Generally, LBCs start rooting within two weeks after planting. The LBCs from juvenile plants produce shoots, which emerge in about three to four weeks, while those from physiologically mature plants start producing tubers within that period. With good management of healthy LBCs, over 90% root without rooting hormones, as recommended in older literature (Evrard et al., 2014).

Other factors affecting rooting include light (full but not excessive), temperature, and moisture. Freshly planted cuttings do not have roots and cannot absorb moisture. However, they lose water from the exposed leaf and leafstalk. To reduce moisture loss, maintain cuttings under high moisture conditions by misting them. Initially, misting may be required almost continuously. Later, the misting schedule should be less frequent and less intense. Other factors, such as the rooting medium and general sanitation, also affect rooting. Cut surfaces are prone to infection, which can cause massive loss. Working with sterilized media, work tools, and surfaces will limit infection.

6

Planting and maintaining LBCs in the screenhouse

Planting in the screenhouse and outdoor protected nurseries generates higher quality vines and minitubers. The conditions within the screenhouse and outdoor nurseries are easier to manage to mitigate possible adverse effects of major biotic and abiotic factors. Also, in a controlled environment, automation could reduce labor costs associated with weeding and applying nutrients.

Planting of LBCs

The procedure for planting LBCs is as follows:

1. Prepare the planting medium and place it in containers of choice.
2. Apply water to keep the medium moist.
3. Insert the entire stem portion and part of the leaf stalk into the moist medium and press lightly. Part of the leaf stalk and the whole leaf should be above the surface of the medium.
4. Water the LBCs very lightly after insertion in the medium.
5. If handling small quantities in pots or flats (seed trays), a plastic hood may be placed over the cuttings to provide a humid atmosphere to enable rooting (Fig. 15). However, rooting is also successful without covering.
6. Place the planted LBCs in a location with bright indirect light.

Figure 17: Plastic covering to enhance the rooting of LBCs.

Rolled-up rectangular plastic strips to hold substrate and cuttings in place can also efficiently use space in the screenhouse (Fig. 18). Use the following steps to plant in plastic strips:

1. Cut thick polyethylene sheets into strips of 10 × 30 cm.
2. Spread moist substrate lengthwise on half of a polyethylene sheet
3. Arrange the stem portion of the LBC at equidistance on the substrate.
4. Fold the empty half of the sheet on the LBCs and roll neatly from one end to the other.
5. Hold the roll in place with a rubber band.

Moisture remains longer in the roll than in open containers, so watering is less frequent. After rooting, plantlets may be transplanted in the field or left in the rolls to produce minitubers.

Figure 18: Planting in plastic strips. 1. Laying LBCs on substrate; 2. Rooting in the roll about 12 days after planting; 3. Shoot emergence from the roll; 4. Plantlets growing from the roll.

Maintenance of LBCs after planting

Regular and general maintenance activities required for plants in the screenhouse are misting during the first two weeks of planting and, later, watering, fertilizer application, pruning, and pest and disease control.

The anticipated type and quality of the venture's product determine what production method to use. A seed producer may wish to root cuttings to transplant in the field, use the cuttings to produce mother plants for further multiplication in the screenhouse or produce minitubers in the screenhouse.

Water supply to LBCs

Misting freshly planted LBCs at intervals with a frequency that depends on the temperature and relative humidity in the screenhouse will produce good results. Misting will maintain a cool leaf temperature and keep the leaves turgid until rooting when the LBCs can begin getting water and nutrients from the substrate. The properties of the growth medium determine the frequency of watering. Water should be provided more frequently during plant establishment and the dry season than during the rainy season. Symptoms of water stress (rolling of leaves) should not be visible before water is applied, as the plant's growth will suffer. Water cuttings using hand watering cans, a garden hose, drip irrigation (Fig. 19.1) or sprinklers (Fig. 19.2). The drip or trickle irrigation system provides water using feeder lines. Water is delivered to the plants at low pressure in drops or trickles directly to the root zone without wetting the foliage. This helps avoid foliar diseases and washing off products applied to the foliage. Perforations along the irrigation line may be made to match the plant spacing. Supplying water only where it is needed at the base of the plant means less water is lost through evaporation. Use soil-moisture monitoring devices to match the amount and timing of water applied to the crop's needs where possible. Consider providing soluble fertilizers through the drip system to feed the crop.

The following are some guidelines on watering the LBCs.

1. Apply mist or fog often early in the propagation process to minimize transpiration and the loss of the LBCs' turgidity.
2. Water should be applied in the early morning or late afternoon, when temperatures are low, to reduce losses from evaporation.
3. Do not apply too much water to have a runoff. Water not used by the plant is wasted and carries away leached nutrients.
4. Organic matter in the planting medium increases water retention capacity, so less frequent watering is needed.
5. Where automatic sprinklers or drip irrigation is employed, adjust timers seasonally as necessary.
6. Apply enough water to keep the growing medium moist but not saturated. A wet environment predisposes plants to foliar diseases, slow growth, and death (Fig. 20).
7. Use water from a good source to avoid introducing pests and pathogens.

Figure 19: Supply of water through a drip irrigation system (1) and an overhead mist system (2).

Figure 20: Too much water and poor drainage of substrate causes yellowing and dropping of leaves (1) and poor growth (2).

Staking of plants in the screenhouse

Yam is a climbing plant, and the vines twine around any available object. Staking exposes the leaves better to light, so tuber yields are better for staked than unstaked plants. Before planting, consider what options exist to stake the plants. Available staking systems include the trellis for individual plants or a collection of plants (Fig. 21), using wooden stakes, bamboo canes, and metal or plastic poles with ropes to direct the plants. Once trained, the plants will cling by twisting around their supports. If the plants are left to sprawl, they will become entangled with each other, and many leaves will be shaded from light, reducing their contribution to yields. Training and supporting plants must be done when they are still young.

Apart from good foliage exposure, harvesting vines for LBCs is easier when plants are staked. In unstaked plants, many leaves are lost in the attempt to untangle leaves and vines (Fig. 22). Also, when any disease starts within the foliage, it may only be noticed once much damage has been done (Fig. 22.1).

Figure 21: Staking of plants grown in different containers—boxes, pots, nursery bags, and rolled plastic sheets using ropes.

Figure 22: Unstaked plants; wasted leaves on the floor resulting from trying to detangle vines and leaves from unstaked plants

Sanitation, disease, and pest management for a good yield of quality seed

Observing sanitary precautions within the screenhouse facility and in all propagation activities is essential to prevent pests and diseases. Use clean growing media, containers, sanitized worktables and implements, and pathogen-free planting materials. With proper sanitation, it will be easy to manage small outbreaks of pests and diseases. Cuttings have exposed surfaces that are prone to disease attack. Hence, it is recommended to sterilize the propagating media before use. The media can be sterilized with steam or irradiation, which controls soilborne pests and diseases. A temperature of about 70 oC for 30 minutes is sufficient to kill many pests and disease-causing organisms (Baker, 1957; Wilkinson et al., 2014). Chemicals can also be used to treat the medium by fumigating or drenching. However, fumigation requires special facilities and poses practical challenges for treating large volumes. Drenching is not considered ecofriendly. Both fumigation and drenching require a high level of safety precautions to avoid harmful exposure to the workers and environment. The heat or chemical treatment will control the medium's fungi, bacteria, insect pests, and nematodes. It is useless to put sterile soil or other media into contaminated containers. So, disinfect pots, nursery flats, benches, water cans, and other tools before use. General sanitation procedures must be maintained to avoid recontaminating equipment and growth media and control pests and diseases. Schedule a regular preventive control of fungal diseases during hot and humid weather depending on local conditions.

Proper ventilation in the screenhouse is critical. When the relative humidity level within the screenhouse is high, fungal diseases may become more severe. High humidity also favors pest growth. High temperatures, the exclusion of rain, and a humid microclimate inside the plant canopy can promote the buildup of fungi and certain insect pests, such as mealybugs, spider mites, and thrips (Fig. 23.1&2). Where this is a challenge, consult local agriculture extension services for advice on control measures.

Figure 23: 1. Fungal attack of unstaked crop planted at high density during high humidity and temperature in a screenhouse; 2. Mealybug infestation.

An outbreak of leaf-eating caterpillars could occur when the soil or substrate is not properly sterilized. The caterpillars are difficult to control as they burrow into the substrate during the day and come out in the evening to feed on the leaves throughout the night (Fig. 24).

Figure 24: Caterpillars and the damage caused.

Harvesting and yield of minitubers

In the screenhouse, the time to harvest minitubers depends on the desired tuber size. It is essential to monitor the size of the tubers and harvest them before they become too big for the container. Stop watering and nutrient application when the right tuber size is attained. Allow the skin of the minitubers to set for at least two weeks before careful harvesting to avoid bruising and wounding.

Entire plants will grow from LBCs to maturity, producing tubers of a few grams to about 500 g in the screenhouse. The tuber size varies depending on the factors of production, such as nutrient and water supply, disease control, size of container, quantity and type of substrate, temperatures within the screenhouse, and crop duration. Tuber yields also depend much on foliage size and exposure of leaves to light. Thus, a single-leafed plant will produce a smaller tuber compared to what a 100-leafed plant will produce, but a 50-leafed plant with good exposure of leaves will grow and yield better than a 100-leafed plant with a high degree of mutual shading of leaves. Generally, to produce minitubers of 1–10 g, LBCs planted in seed trays will grow for 3–4 months (Fig.

25). This seed size is adequate as a breeder or foundation seed to produce the next seed class. Mother plants pruned 1–3 times will also yield tubers of 50 to 300 g at the end of the production cycle (Fig. 26).

Figure 25: Plants growing in polystyrene nursery trays and minitubers of 2–10 g harvested 3 months after planting LBCs in the screenhouse.

Figure 26: Tubers up to 300 g harvested from mother plants grown in boxes eight months after planting 5 g minitubers. Mother plants were pruned three times for LBCs.

7

Challenges of screenhouse production of seed yam

Seed yam production in the screenhouse can be challenging, but the setbacks are surmountable using best practices. However, the limited research on the yam value chain generally and screenhouse production, in particular, implies that there will still be several gaps in knowledge. In the yam belt of West Africa, where over 90% of world yam is produced, yam thrives in the open field, on fertile soils, with abundant sunshine and a temperature of 25 to 30 °C. While it may be easy to standardize some factors of seed yam production in the screenhouse, temperature control has been critical. Since the design of the screenhouse affects internal temperature, it is pertinent to use the correct type of structure to suit the location and climate. The environmental requirements of yam were only partially considered when the screenhouses currently used were constructed. During the hot and dry period in the yam-producing zone, temperatures get much higher than what yam requires for optimal growth; 42 °C have been recorded in the screenhouse in Abuja. At such high temperatures, the crop's development ceases. Attempts to keep temperatures below 30 °C have not succeeded but have added to the cost of production. As a result, year-round production may only be possible when this challenge is resolved. Some of the production challenges in the screenhouse and their mitigation are presented in Table 3.

Table 3. The challenges of seed yam production in the screenhouse and how to mitigate them.

Challenge	Mitigation
Excessive heat in the screenhouse during hotter periods of the year.	Produce crops during cooler periods; install a cooling system within the screenhouse; use a model of the screenhouse to suit the location and climate. Plant the mother garden early, 4 - 6 weeks before the end of the hot period, to take maximum advantage of the cooler period. The tubers will sprout, and young shoots will emerge from the soil during the hot period. Vigorous growth will start as soon as temperatures become favorable.
Tubers protrude from the substrate or are malformed (Fig. 27).	Use the right-sized containers and fill them with an adequate quantity of substrate for the desired size of tubers.
Insect pests feed on plants, especially caterpillars and mealybugs.	Maintain proper hygiene in the screenhouse, treat substrate, equipment, and work surfaces adequately, and apply the recommended insecticide in case of high incidence.
Foliar fungal and viral diseases	Establish plants in a screenhouse using virus-free starting material. Inspect plants regularly and carry out periodic tests to confirm the disease status of plants that exhibit symptoms. Maintain proper hygiene within and around the screenhouse. Follow a routine of preventive measures, including using fungicides to control the incidence of fungal leaf pathogens. Avoid uncontrolled movement in the screenhouse.
Suboptimal establishment of planted LBCs	Mist and water cuttings should be done regularly to maintain leaf turgidity, especially during the first two weeks of planting. Provide adequate protection against harsh environmental conditions.
Physiological cracks (growth cracks) on tubers (Fig. 28)	Provide adequate and regular water and nutrients to plants.

Figure 27: Protruding and malformed tubers produced in shallow containers or substrate.

Figure 28: Growth cracking due to an uneven availability of water, e.g., excessive short-term irrigation followed by a period of dryness.

8

Field production of seed yam using leaf-bud cuttings

Planting in the field can be done using freshly prepared LBCs or LBC-derived plantlets produced in a screenhouse or nursery. Where good shade material is available, direct planting of LBCs in the field is recommended.

Direct planting of unrooted leaf bud cuttings in the open field

The advantage of inground planting is that the plants will have more access to water and nutrients since the soil does not dry out as quickly as most substrates in containers. As soon as rooting starts, there is more space for root systems to grow. Yam farmers customarily plant tubers directly in the field with minimal attention given to the field until sprouting starts, when there is a need for weeding and other agronomic practices. However, if LBCs are handled similarly, the planted materials and other inputs would be lost since the cuttings lack roots to absorb water and nutrients from the soil. When using LBCs for yam multiplication, there is a need to observe basic nursery practices, as is common in the propagation of many horticultural crops. The LBC requires a good shading system. After planting, the LBCs require tender care until they develop sufficient roots and shoots to manufacture photosynthates for growth and development. With good management before and after planting, more than 90% of the LBCs will survive. The following procedure will ensure a good establishment of LBCs.

1. Select fertile, well-drained loamy soils that are devoid of stones.
2. Cultivate the soil thoroughly into a fine tilth.
3. Make about 1.2 m wide or less beds of any convenient length with 0.5 m between beds.

4. If available, apply a 1–2 cm thick mulch of fermented rice husk on the beds. A good mulch application effectively controls weeds on the beds throughout the growing season.
5. Provide adequate shade over the bed. Use shade nets or any other material that can provide sufficient shade over the LBCs.
6. Apply water to wet the mulch and soil.
7. Mark out planting holes at a spacing of 10 × 10–30 cm (Fig. 29.1), depending on the desired size of the tubers. Generally, the total tuber yield increases with high plant populations, while the mean tuber size decreases.

Prepare LBCs as in section 5.2, of this document.

Remove the prepared LBCs from the fungicide solution and plant immediately in the well-watered beds, burying the stem portion entirely in the soil and leaving about half of the petiole and the entire leaf blade above the soil. Plant early in the morning or late in the evening, avoiding hot periods of the day as much as possible (Fig. 29.2).

Press the soil gently around the planted cutting.

Mist the leaves after planting and repeat misting at intervals during the day to ensure that the leaves stay turgid. Maintaining leaf turgidity during the first two weeks of planting is critical since rooting usually occurs during this period (Fig. 29.3).

Spray a broad-spectrum fungicide (3 g Mancozeb/l of water) to control fungal infection occurrence during the early growth stage.

- Remove the shade progressively when plants have 3–5 leaves, from about 6 WAP. Reduce the amount of shade before taking it off completely. Sudden exposure of the young plants to the sun will result in leaf scorching and defoliation. Scorching can be devastating if shoots are not produced, as frequently occurs when LBCs are obtained from physiologically old mother plants. However, if the plant has a young shoot, the scorching effect is reduced because only the oldest planted leaves will be damaged (Fig. 29.4).

- Maintain the crop by following good agronomic practices for weeding, staking, fertilizer application, and harvesting.

A significant advantage of direct field planting of LBCs under shade is that after rooting, plants thrive without going through the physiological shock stage associated with plantlets that are first rooted in a nursery before transplanting in the field.

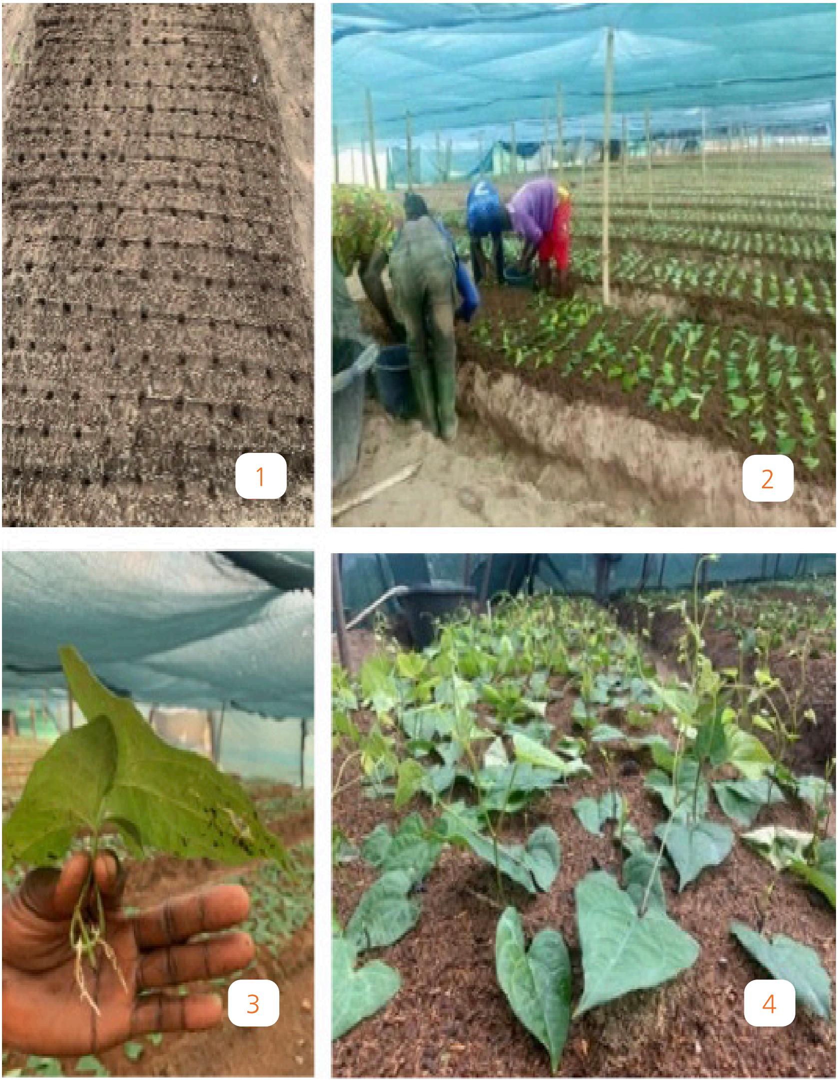

Figure 29: 1. Bed prepared for planting (mulched with fermented rice husk and marked); 2. Planting in beds under shade; 3. Rooted LBC about two weeks after planting; 4. Shoot emergence from LBCs (4 WAP).

Transplanting of rooted seedlings

Leaf-bud cuttings can be rooted in the protected screenhouse before transplanting to the open field. Transplanting LBCs should be considered when the availability of shade material for field planting of unrooted cuttings is a challenge. The screenhouse provides optimal rooting and sprouting conditions for plant survival and uniformity. This method can avoid some environmental hazards and extend the growing season. It also ensures that only well-developed plantlets are transplanted to the field. A well-grown transplant has healthy white roots with four to seven open leaves about eight weeks after planting the LBCs.

Plants will perform better if rooted cuttings are planted with minimum root disturbance, which can cause transplant shock or trauma, hence poor establishment. To enhance plant survival, water the plantlets an hour or two before removal from the nursery container, ensuring that the potting soil adheres to the root ball (Fig. 30.1), reducing root damage before planting. The planting site should also be moist before planting. It is easier to set out plantlets grown in individual pots or cells with minimal root disturbance. Root damage is unavoidable when separating the plants in other types of nurseries. However, ensure that the plants are taken with as much root as possible by removing the whole mass of roots and potting soil intact. Each plant should have a well-developed root system before taking it out for planting.

Transplant shock can interrupt plant growth and set them back by some weeks. Young transplants take several weeks to develop new roots and draw moisture and nutrients from the surrounding soil. Minimize the shock by carefully considering the weather conditions and ensuring the new transplant receives adequate moisture after planting it. Transplanting should be done preferably on cool, cloudy days, in the morning or late afternoon, when the sun's heat is not intense and the wind is calm. Avoid transplanting after the start of tuberization or when plants are overgrown in the container and have a tangle of congested roots (Fig. 30.2). When plants establish and growth resumes, maintain them by following the agronomic practices mentioned in the next section (Fig. 30.3).

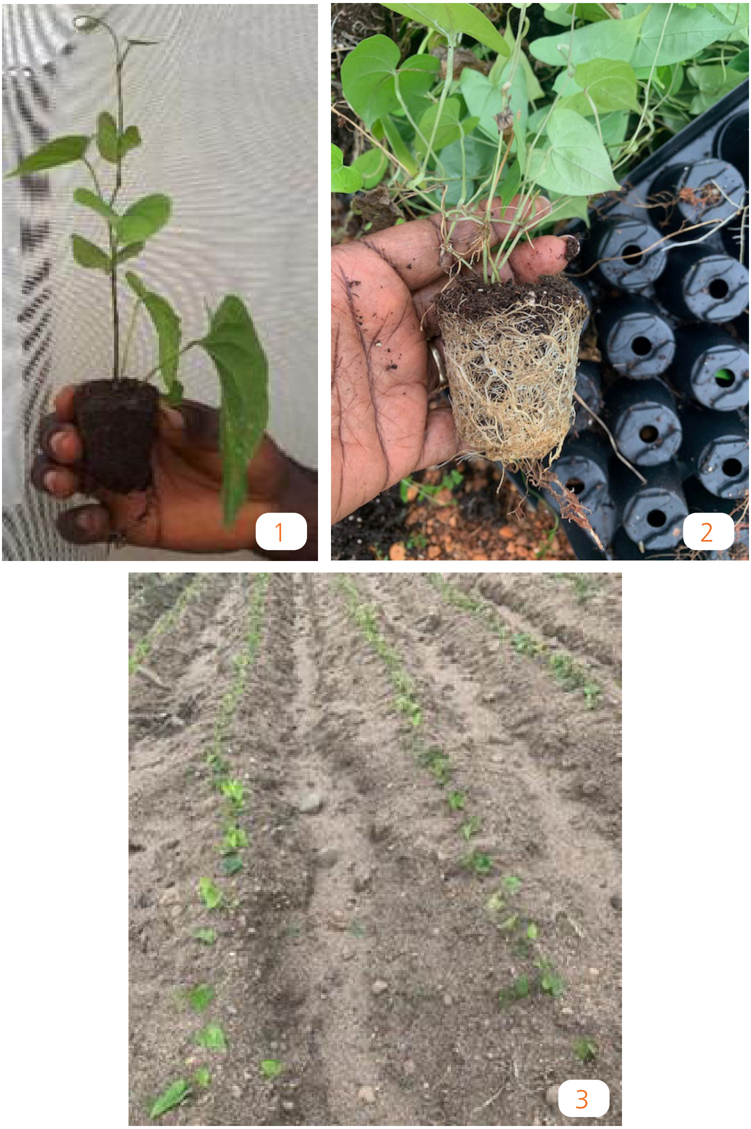

Figure 30: 1. Good LBC plantlet with a substrate ball around the roots; 2. Overgrown plant with congested roots; 3. Field transplanted with plantlets from LBC rooted in the screenhouse.

9

Agronomic management of the established seed yam crop in the field

After planting, good practices for water supply, pest and disease control, staking and nutrient management should be observed to achieve good yields and quality seeds.

Water application: After removing the shade, regular crop maintenance becomes easy. LBCs in the beds can be watered using a watering can, a hose, or a drip irrigation system. The watering frequency is important because less water will result in a poorly developed root system. In contrast, too much water could result in waterlogged conditions, causing the roots to rot. Fertilizers may be added to the irrigation water.

Pest and disease management: Adopting planned plant protection measures is necessary for good plant establishment. To avoid transferring infected plants to the field, maintain only virus-free plants in the screenhouse. Regular inspection of plants and immediate action against pests and diseases will reduce the chances of rapid spread. Watch out for caterpillars that feed on yam leaves at night and burrow into the soil during the day. They can cause significant loss of plants in the field over a short period.

Weed management: The plants should be as weed-free as possible. Adequate mulching with materials such as rice husk will control weeds, and only periodic handpicking may be necessary. Planting at close spacing on beds is also suitable for weed control. Yams have a shallow root system, so weed carefully to avoid destroying the roots. Heap soil at the base of plants to prevent the exposure of roots and tubers to the weather and rodents.

Staking: Early staking with trellis when plants have 5–10 leaves gives them a good start. Staking makes weeding and other crop maintenance practices easy (Fig. 31). It also exposes the foliage better to the sun, resulting in higher yields.

Figure 31: Staked plants in the field 14 weeks after planting.

Fertilizer application: The quantity of fertilizer will depend on the soil fertility and plant population. Seek advice from a competent source on the type and amount of fertilizer to apply. The fertilizer NPK 15:15:15 is generally recommended because its high potassium content favors tuber development.

Harvesting: The seed yam crop matures in about five months in the field. In rainfed culture, the foliage will senesce two to three weeks after the last rain. Harvest carefully when the tuber's skin is firm to avoid bruising and wounding. As with the screenhouse production of tubers, field plants that grow to maturity with only the single leaf or double leaves planted will also produce tuber(s) (Fig. 32).

Figure 32: Tubers harvested 20 WAP from plants with shoots (a) and tuber from plants without shoots (b).

10

Storage of LBC-produced seed tubers

This section provides advice on storing tubers produced in the screenhouse and field. The duration of seed tuber storage is a function of their postharvest physiology and pre-storage activities, including how they are cultivated, harvested and handled. Storage should be under conditions that the sprouting of tubers is as close as possible to when the seed is needed for planting. While studies are ongoing on storage options for minitubers, especially those of <10 g produced in the screenhouse, three critical environmental factors are temperature, humidity, and ventilation. The following guide can reduce losses in storage.

1. Allow wounds on tubers to cure and form a callus by spreading them out in a well-ventilated space in the store or a shaded area before bulking for storage.
2. Keep seed tubers in a cool place with good ventilation to prevent moisture buildup, which can lead to rots. Temperature fluxes can precipitate premature sprouting.
3. A high humidity of about 95% will reduce dehydration. The moisture content of the yam tuber can be up to 80% and needs to be maintained to avoid weight loss and vigor. High humidity is also essential for wound healing and curing.
4. Do not store seed in direct sunlight.
5. Store preferably in breathable materials, such as paper, burlap sacks, mesh bags, or wooden crates. Whatever material is available, ensure that it has good ventilation. Allow spaces around the storage units.
6. Store only healthy tubers and watch for rot, as one bad tuber can spoil the lot. Pests such as mealybugs and nematodes multiply in storage, so keep them out of the store.

11

Challenges in field planting of LBCs

A producer may encounter the following challenges when growing LBCs in the field.

1. Due to the harsher environment outside, the water supply to newly planted LBCs in the field must be more diligent than in the screenhouse. A more elaborate arrangement is required for adequate water supply.
2. If the shade is removed abruptly without acclimatization, plants that do not produce shoots may be lost due to sun scorch (Fig. 33.1,2). There is better survival when plants have two or more new leaves before the shade is removed.

Figure 33: Older leaves of emerged plants are scorched when the shade is removed abruptly. The emerging shoots survive (1), but loss may be severe if there are no shoots (2).

3. Obtaining good-quality shade material to cover a large area of land in the field can be challenging. Shade nets are currently in use, but the high cost and poor quality of what is available in markets in areas of production necessitate the search for alternative shade materials.
4. Nonuniformity in soil conditions and mutual shading of plant foliage make the uniformity of tuber size challenging to attain.

As a preliminary recommendation, plan production in the screenhouse and field to avoid harsh weather and use locally available materials to provide shade. Further research will provide solutions to the current challenges.

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