Chapter 15
Commercially Sustainable Cassava Seed Systems in Africa

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Abstract Cassava is an important crop in sub-Saharan Africa for food security, income generation, and industrial development. Business-oriented production systems require reliable supplies of high-quality seed. Major initiatives in Nigeria and Tanzania have sought to establish sustainable cassava seed systems. These include the deployment of new technologies for early generation seed (EGS) production; the promotion of new high-yielding and disease-resistant varieties; the updating of government seed policy to facilitate enabling certification guidelines; the application

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of ICT tools, Seed Tracker and Nuru AI, to simplify seed system management; and the establishment of networks of cassava seed entrepreneurs (CSEs). CSEs have been able to make profits in both Nigeria (US$ 551–988/ha) and Tanzania (US$ 1,000 1,500/ha). In Nigeria, the critical demand driver for cassava seed businesses is the provision of new varieties. Contrastingly, in Tanzania, high incidences of cassava brown streak disease mean that there is a strong demand for the provision of healthy seed that has been certified by regulators. These models for sustainable cassava seed system development offer great promise for scaling to other cassava-producing countries in Africa where there is strong government support for the commercialization of the cassava sector.

15.1 Introduction to Cassava and Cassava Seed in Africa

15.1.1 The Importance of Cassava in Africa

Cassava was introduced to the Gulf of Guinea in West Africa from Brazil in the sixteenth century. Later introductions were made to coastal areas of East Africa in the eighteenth century, and the crop diffused gradually into the interior. Cassava's value as a food security staple was recognized during the early part of the twentieth century, and its cultivation was widely encouraged. However, it was during this period – the 1920s and 1930s – that the crop faced its first major disease challenge as epidemics of cassava mosaic virus disease (CMD) spread to all of the major production zones, leading to substantial yield losses.

Cassava is a semi-perennial shrub (*Manihot esculenta* Crantz), which grows best in well-drained soils in regions with tropical temperature regimes where there is well-distributed annual rainfall of >800 mm. Once the crop is established, however, it is tolerant of periods of drought and will yield in soils which are unsuitable for more nutrient-demanding crops such as maize. Since the 1990s, increased levels of governmental support have led to expanded cassava production in several African countries. Total production in Africa increased from 70.3 million tonnes in 1990 to 192.1 million tonnes in 2019, a 173% increase, although most of this growth resulted from an expansion in the cultivated area (+151%) rather than from higher yields (+8.6%) (FAOSTAT 2021). These changes have led to a shift in the global dynamic of cassava cultivation, as Africa's share of total production has increased from 46% in 1990 to more than 63% in 2019. Although this change is partly a result of the need for food production to keep pace with population increase, it has also arisen from an increasing recognition of the industrial value of the cassava crop. Rapid urbanization has opened up new markets for processed cassava products, and there have been increasing efforts to strengthen cassava value chains. The increased commercialization associated with these changes has provided new opportunities to modernize the seed systems that are a key component of efficient cassava value chains.

15.1.2 The Fundamental Importance of Cassava Seed

Although cassava plants produce true seeds under favorable environmental conditions, these are genetically heterogeneous and may not germinate readily. By contrast, stem cuttings are clones of the parent plant, retaining desired characteristics. Cuttings sprout readily in moist soils, are relatively easy to handle, and have become the primary propagule for establishing a new cassava crop. However, there are several drawbacks to this form of vegetative propagation. Firstly, the cuttings are bulkier and more prone to deterioration than true seeds, and, secondly, there is a high likelihood that pathogens that infected the parent stock will be carried directly via the cuttings into the newly established plants. This is particularly true for viruses. In Africa, the two most important biotic production constraints are CMD and CBSD (cassava brown streak disease), both of which are propagated by stem cuttings as well as through transmission by a whitefly insect vector. CMD is distributed wherever cassava is grown in Africa, while CBSD occurs in East, Southern, and Central Africa, although it continues to spread further westward (Legg et al. 2015). Both diseases can be effectively managed with clean planting material of resistant varieties, but few farmers currently have access to this material. This situation provides a clear justification for investments in improving seed systems with the aim of the sustainable delivery of high-quality seed to farmers. This will necessarily involve efforts to shift from entirely informal seed systems, where farmers share or trade planting material with no regulation of the provenance, characteristics, and health of the material, toward more formal seed systems, where the source, identity, and quality of planting material are regulated. An extensive monitoring survey of cassava varieties and landraces being grown in Nigeria, using DNA fingerprinting to ascertain the identity of the varieties in the field, showed that about 20% of respondents erroneously thought they were growing a landrace when it was an improved variety, and about 13% thought the opposite (Wossen et al. 2017). This exemplifies the importance of being able to source seed that is true-to-type of the desired variety. Experience from Nigeria has also shown that high-yield potential and other quality traits are attributes of cassava seed that can encourage investment in commercial seed systems (Bentley et al. 2020b).

15.1.3 Social Background to Cassava Seed Systems

Informal seed systems continue to predominate for most crops in most countries of sub-Saharan Africa. McGuire and Sperling (2016) estimated that 90.2% of seed is accessed through informal systems in smallholder farming communities, particularly those in sub-Saharan Africa. For cassava, the balance is even more heavily skewed toward informal systems. Even in countries where there have been large-scale interventions to promote more formal seed systems, the quantity of formal seed produced still remains less than 1% of the total volume of seed planted by farmers. Both women and men are active in cassava production, processing, and marketing, although in Nigeria, men play a greater role in planting, crop management, and harvesting, while women are primarily responsible for farm and household-level processing (Nweke et al. 2002). Up to 30% of men and women indicate that they sometimes purchase cassava planting material, although main sources are farmers' own fields or those of their neighbors or friends (Teeken et al. 2018). Gender studies on cassava production systems in both West and Southern Africa have demonstrated clearly, however, that men play an increasingly dominant role as production, processing, and marketing systems increase in scale and become more commercialized (Forsythe et al. 2015). These trends have highlighted the importance of recognizing gender effects as more systematic efforts are made to increase the commercial potential of cassava seed systems.

15.1.4 Why a Commercially Sustainable Seed System for Cassava Is Critical

There have been efforts made over several decades to develop cassava varieties in Africa that are high-yielding and disease-resistant and meet the quality requirements of farmers. These have frequently been coupled with large-scale seed dissemination schemes (Dixon et al. 2003). However, prior to 2010 there was little attention given to the sustainability of seed dissemination programs, meaning that when support for the program came to an end, the provision of improved seed ceased. Furthermore, it was also widely considered that disseminating seed of disease-resistant varieties was enough, whether or not the seed was of good quality. More recently, however, it has become widely recognized that improved seed programs can only be sustained if commercial mechanisms are incorporated. A significant proportion of cassava farmers in Africa already pay for cassava seed, predominantly through the informal sector, and as the sub-sector becomes increasingly business-oriented, this proportion will increase. Commercial seed systems grounded on the formal sector are developing rapidly for major grain, legume, and vegetable crops in Africa, as well as for potato, which provides a useful comparator example for cassava in view of its similar vegetative propagation and bulkiness. Commercially sustainable seed systems for cassava, which deliver certified seed of improved varieties, offer great potential benefits to farmers, including increased productivity resulting from low disease and pest levels, as well as an assurance that what they pay for is what they get. Commercial seed systems that supply high-quality products also provide substantial new income-generating opportunities for farmers. Furthermore, structured commercial cassava seed systems that provide quality assurance may enhance dissemination of improved varieties to smallholder farmers and inform breeding programs on varietal demand and trait preferences, which in turn will result in a more dynamic and productive cassava economy.

15.2 The Essential Elements of a Commercially Sustainable Seed System for Cassava

15.2.1 Markets for Cassava Products

Vibrant markets for cassava products are an essential driver for the development of sustainable seed systems. Cassava is consumed as food or feed or is used to make industrial products like starch and biofuels. Although the starchy roots are the main food product, the leaves are also consumed in certain regions. The Cassava Monitoring Survey in Nigeria (Wossen et al. 2017) showed that cassava is used mainly for food within the household and as a cash crop, with about 50% of the cassava produced sold for cash income, primarily for processing into food products. The demand for cassava roots is increasing due to more food manufacturing to meet demand in growing urban populations. This includes industrial products such as starch and flour but predominantly processed food products such as gari and fufu (Bentley et al. 2020a). As trade in seed grows, certification will be increasingly required for commercial seed production as there will be a clear benefit to planting material that is of high quality and of known provenance of specific improved varieties (Thiele et al. 2021). This sets the stage for establishing a sustainable seed system. This review presents two contrasting market demand situations for high-quality cassava seed. In Nigeria, where disease problems are relatively minor, there is strong demand for high-yielding farmer-preferred varieties such as TME 419. In Tanzania, however, the significant losses incurred by farmers as a result of infection of local varieties by the virus diseases CBSD and CMD means that there is strong willingness to pay for healthy seed of disease-resistant varieties. Studies in Tanzania and Uganda suggest that farmers are willing to pay a price premium of between 8 and 25 percent for certified stems relative to uncertified material (MEDA 2016).

15.2.2 Availability of Early Generation Seed (EGS) for Seed Entrepreneurs

Formal seed systems, where seed is certified, have been effective for cereal crops such as hybrid maize, but these have rarely been applied to vegetatively propagated crops such as cassava until recently. Large-scale cassava seed production programs have worked intermittently through donor driven initiatives since the 1990s. In seed multiplication projects during this period, an approach of primary, secondary, and tertiary multiplication of cassava stems was applied by the public sector and NGOs. The outbreak of CBSD in East Africa in the 2000s meant that it was very difficult to multiply healthy planting material using existing approaches, and there was a recognition that more formal systems for seed quality control were required. This led to the inclusion of cassava among the seed crops that were officially certified in countries such as Nigeria and Tanzania, although it was recognized that seed certification for cassava would be much more challenging than that for cereals, since cassava seed is bulkier and perishable.

Two large Bill & Melinda Gates Foundation (BMGF) funded projects – BASICS in Nigeria and BEST in Tanzania – have provided impetus both for the completion of policies and regulations relating to the certification of cassava, as well as for activating EGS production efforts (Bentley et al. 2020b). This has involved recruiting a range of public and private organizations for EGS production and delivery. By 2021, several other countries had also implemented similar types of activities, including Burundi, the Democratic Republic of Congo (DRC), Rwanda, and Uganda. In addition, common cassava standards were established as part of the ECOWAS harmonized seed regulations adopted by the West African member states.

EGS production for cassava is still in its infancy, with formal seed accounting for less than 1% of the total, and it is vital that government and development agencies continue to nurture this evolving system. Furthermore, awareness raising and advocacy campaigns on the value of quality seed and seed replacement are important requirements for creating demand for quality seed, which is pivotal for a successful cassava EGS system. Although many African countries have seed laws that provide guidelines for the certification of seed of vegetatively propagated crops, in most cases these are unrealistically stringent and are not applied. A key new requirement for establishing effective commercial seed systems has therefore been the revision of certification guidelines so that they serve both to enhance seed quality while at the same time enabling seed producers to succeed. Costs and benefits associated with these revised certification requirements should be quantified and integrated into business models for cassava seed entrepreneurs.

15.2.3 Productive, Disease-/Pest-Resistant and Farmer-Preferred Varieties

Acquisition of new varieties – whether for their pest/disease resistance or higher yield potential – is the key incentive for farmers to purchase cassava seed. This means that establishing and maintaining a strong breeding pipeline is a key requirement for sustainable cassava seed systems. Productive, disease-/pest-resistant and farmer-preferred varieties are developed through breeding. Breeding is complex and time-consuming as new germplasm needs to be tested for qualitative and quantitative traits in multiple environments. This process may take up to 10 years before varieties with the desired traits can be released. Adoption is enhanced by involving farmers in on-farm evaluations. Since CMD and CBSD are the two most important disease constraints affecting cassava production, the development of varieties resistant to both is a key breeding priority. Requirements for virus-resistant varieties are less stringent in parts of Africa not yet affected by CBSD, which includes all of West Africa as well as the western part of Central Africa. In these regions, breeding efforts therefore place a greater emphasis on yield and the quality characteristics of both fresh and processed roots.

15.2.4 Technologies for Rapid Propagation

Tissue culture The multiplication throughput of clonal crops such as cassava has been significantly increased by using in vitro propagation methods (Ng 1992). These have also helped to introduce virus-tested, true-to-type plantlets into seed systems. Tissue culture activities for cassava are well established in several African countries, such as Nigeria, Ghana, Kenya, Rwanda, and Tanzania. The use of cassava tissue culture plants for commercial production of cassava seed has not been successful, however, particularly in countries such as Nigeria, in spite of the high demand for seed of improved cassava varieties. This is mainly due to the relatively sophisticated laboratory requirements and associated high cost of individual plantlets, as well as the difficulties that users often face in the post-flask management procedures. There has therefore been a need to explore other rapid propagation technologies for early generation seed.

Mini-cutting propagation The traditional method of cassava propagation entails the use of a 20–25 cm cutting that is cut from a mature stem that is usually 1 to 3 meters in length. Each planting stake can have five to ten nodes depending on the variety. Some varieties have nodes that are close together, while in other varieties the nodes are far apart. In the 1990s, breeders sought to explore the use of shorter planting materials (mini-cuttings) to obtain more planting materials for breeding trials. This led to the emergence of nodal cutting technology, where stems are cut into smaller pieces, about 5 cm long and which usually have two nodes. The technology has not been widely used for commercial seed production, so little is known about its performance when tailored toward quality seed production. Nevertheless, when used to multiply planting material for trials, the small size of the cuttings frequently results in many drying out and subsequently failing to sprout when planted. Also, the productivity of both the vegetative part and roots is hampered due to reduced transportation and distribution of assimilates in the plants. A further drawback is the labor required for preparing large volumes of nodal cuttings. For these reasons, mini-cutting propagation has not been widely used in cassava seed systems.

Semi-autotrophic hydroponics (SAH) SAH was developed by the SAHTECHNO Company (Argentina), to enhance the production of potato plantlets for greenhouse or field transplantation. In 2016, the International Institute of Tropical Agriculture (IITA) adapted SAH technology for rapid propagation of cassava and subsequently for yam. SAH offers the benefit of tissue culture grade quality planting material at lower cost and under "low-tech" conditions. SAH makes use of the autotrophic capacity of the plant to grow in a friendlier environment, where there is more effective gas exchange and where growing conditions are more natural (Rigato et al. 2000). SAH is a technology focused on the mass propagation of virus-free plants derived from tissue culture. It is low-cost and easy to set up for commercial seed production and enhanced multiplication in breeding programs. SAH has recently been adapted for cassava propagation in Nigeria. Currently, there are five SAH labs operating in Nigeria: one each at IITA in Ibadan and the National Root Crops Research Institute (NRCRI) in Umudike and three at private companies. SAH laboratories have also been established in other African countries, including the Democratic Republic of Congo (DRC), Malawi, Tanzania, and Zambia.

15.2.5 Seed Quality Assurance and Certification

Guidelines for quality assurance Cassava has not traditionally been included as part of formal systems for seed quality assurance. This is partly because there is less international trade of cassava, and it has less commercial value than many other crops. This applies in all parts of the world where the crop is grown, including countries where there is a high degree of commercialization, such as South and Southeast Asia. In Africa, regional efforts to harmonize seed quality regulations, such as those included in COMESA's seed trade harmonization regulations of 2014, have not included cassava. The CMD and CBSD virus disease pandemics of the 1990s and 2000s, however, highlighted the need to have mechanisms for the production and trade in cassava seed that was free of these two diseases. Models for seed quality certification were piloted by national seed certification agencies in Tanzania and Nigeria and have subsequently been improved and scaled out to several other countries, including Burundi, DRC, and Rwanda. Specific details of the protocols used in each country vary, but all cases address the key elements of varietal purity, pest/disease incidence levels, virus testing, isolation distance, and the number of ratoon crops allowed.

Technologies and infrastructure for seed quality assessment including lab and field diagnostics Seed certification systems normally include field inspections, where visual assessments are made of pest/disease incidence, as well as some laboratory testing for higher seed categories (pre-basic/breeder seed). Most national seed certification authorities have existing human and physical capacity for field and lab assessments, which are primarily used for the major seed crops, such as the cereals, oilseeds, and grain legumes. This means that there is at least some potential to adapt these capacities to implement cassava seed quality assurance. However, seed inspectors will need specific training on cassava. More inspectors may need to be hired, and decentralized, in order to provide enough inspections for new cassava seed entrepreneurs. Such efforts need to ensure that the seed certification systems are affordable and reliable. For example, in Tanzania, decentralization efforts focused on training existing extension staff as authorized seed inspectors (ASIs) who are able to conduct basic certification assessments on behalf of the regulatory authority (Tanzania Official Seed Certification Institute, TOSCI). This has greatly reduced costs since ASIs are based throughout the seed production zones (Douthwaite 2020). New digital tools, such as PlantVillage Nuru, are available for field-based disease/pest identification for cassava, although visual inspections continue to be the main method used by the ASIs. Laboratory-based virus diagnostics may be required at higher levels of the seed system, particularly in countries where the inconspicuous CBSD occurs. Novel diagnostic methods are likely to become more widely used as they reduce virus testing costs and are easier to conduct in lightly equipped laboratories. Currently, new methods such as loop-mediated isothermal amplification PCR (LAMP) are being validated with regulatory authorities in several countries.

Electronic information systems in support of certification, business registration, and marketing Cassava seed production involves a chain of interconnected activities between various institutions and entrepreneurs formally recognized to produce and market different classes of certified seed of released varieties. The lack of awareness about seed regulations, cumbersome procedures, and the high cost of seed certification are some of the challenges to implementing seed certification. To simplify this process and integrate the cassava seed production value chain, IITA developed the "Seed TrackerTM" ICT app (www.seedtracker.org/cassava) that digitally links multistage seed value chain actors. The app is usable on any Internet-enabled device, including mobile phones, tablets, and personal computers. It can be used to collect and organize seed production data and for real-time tracking of seed production. It generates maps, offers secure accounts for data input and retrieval, and provides a diverse set of analytics (Fig. 15.1). The app features customized digital data collection forms with offline data collection allowing it to be used in areas without an Internet connection, and it relays data remotely when the device gets connected to Wi-Fi. The application is tailored to national seed certification systems and provides support for registration of seed producers, registration of seed fields, field inspection, and certification of seed lots and generates barcoded labels for traceability.

The National Agricultural Seed Council of Nigeria (NASC) in 2017 and TOSCI in 2018 adopted Seed Tracker for e-certification of cassava. Seed certification officers were trained to perform e-seed certification and manage seed quality assurance activities using Seed Tracker. In 2019, NASC adopted Seed Tracker as a national e-certification platform and expanded its use to all crops. Seed Tracker offers a "one-stop shop" for information on seed quantity, location, and variety, enabling buyers to know when and where certified seed is available. It therefore supports the adoption and impact of improved varieties developed through breeding programs. Real-time reporting and the simplification of the administrative processes associated with certification mean that Seed Tracker can help seed system stakeholders overcome many of the problems traditionally associated with formal seed certification programs. Regulatory agencies are also using experience gained from other

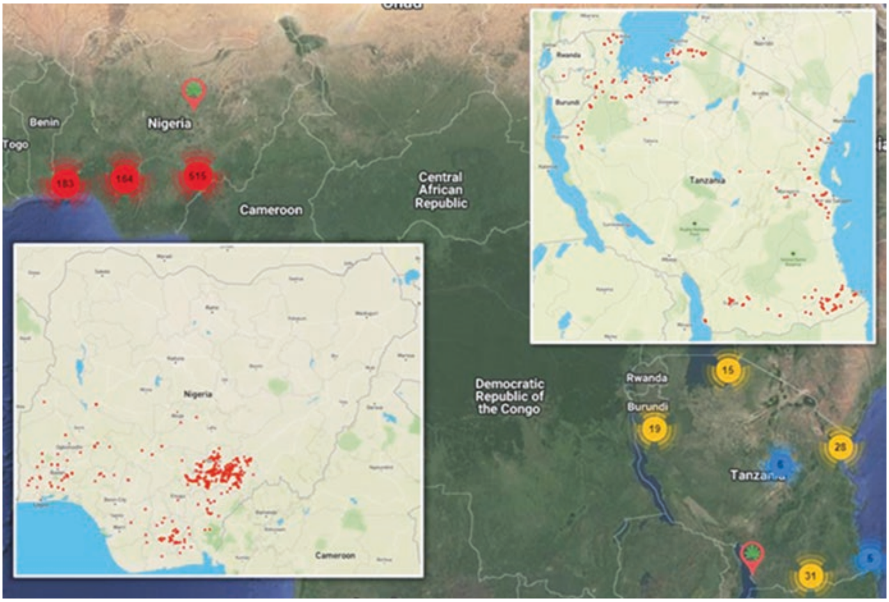

Fig. 15.1 Distribution of commercial cassava seed producers registered on Seed Tracker in Nigeria and Tanzania

more commercialized crops to develop ICT systems for the digital tagging of seed packages in order to prevent the sale of counterfeit seed.

15.2.6 Enabling Environment for Business Development

There are several important requirements for creating an enabling environment for commercial cassava seed system development. These include the free flow of information and data among all system participants, availability and access to sources of high-quality seed that targets demand, strong markets for cassava products, a business-friendly agricultural policy with ready access to business development services, and the system-wide application of a seed regulatory system that promotes quality while remaining affordable.

Information flow Seed producers should be aware of market demand, of available varieties to meet that demand and of the crop management requirements for producing high-quality cassava seed. Root producers need information about the relative benefits to be gained from improved seed. Processors should have access to information about sources of roots, their quality traits, and markets for processed products. Finally, for effective quality control, seed regulators require a thorough understanding of the network of seed producers with easy, real-time access to information about the producers and their seed crops.

Availability and access to seed In order for a cassava seed system to flourish, seed producers at all levels, as well as root producers, need to have easy access to sources of quality seed. Unlike seed of cereal crops or grain legumes, cassava seed is not typically sold through markets or input dealers. Informal systems prevalent in most cassava-producing countries in Africa are dominated by local exchange with neighbors and relatives, with occasional roadside selling. Newly emerging commercial seed systems for cassava are addressing the issue of access and availability by enhancing information systems to openly share seed information such as variety, quantity available, price, and location.

Strong markets Cassava producers are paying greater attention to the commercial potential of the crop as new processing businesses and market outlets are set up, most notably in Nigeria. Where cassava is sold, the importance of productivity is increasingly recognized, leading to increased farmer demand for improved high-yielding varieties and a greater willingness to invest in inputs such as certified seed. Therefore, commercial seed systems are unlikely to succeed for cassava, unless there is a commitment to establish and sustain output markets for fresh or processed cassava products.

Business-friendly agricultural policy Business policy can have a critical impact on the likelihood of success for agricultural business, including seed production. Common impediments to success can include bureaucracy that can make it difficult to set up and run a business, weak government support for the agricultural sector, lack of access to finance, and poor infrastructure in agricultural areas. In countries where commercial cassava seed systems have not yet been established, business training may be required to support cassava seed entrepreneurs setting up businesses for the first time. Cassava seed entrepreneurs should also have ready access to the range of business development services required to establish and maintain their new seed businesses, including access to inputs, marketing advice, telephone and Internet infrastructure, as well as financial services.

Practical seed regulatory system Seed policy needs to be market-responsive, widely known, and implemented well. The first step for many countries will be defining guidelines for affordable seed quality regulation. The threats posed by vegetatively propagated viruses, such as those causing CMD and CBSD, as well as an increasing demand for greater productivity, have encouraged the implementation of formal systems for seed quality assurance in several countries. However, these certification systems must enhance the quality of cassava seed, be applied in a sustainable way, and be practically scaled beyond a project context, with affordable tariffs that are appropriate for the business plans of seed producers at each level of the system.

15.3 African Experiences of Establishing Sustainable Cassava Seed Systems: Case Studies from Nigeria and Tanzania

15.3.1 Building a Sustainable Integrated Seed System for Cassava in Nigeria (BASICS)

The context: cassava in Nigeria in the 2000s Nigeria is the world's largest producer of cassava (59 million t/yr). About 90% of cassava in the country is processed as food, 9% for industrial flour or starch, and less than 1% of the cassava output is exported. For food, most is produced and processed locally into gari (grated, fermented, and toasted to a dry granular flour), fufu/akpu (fermented wet paste then cooked with additional water to make a thick porridge), or lafun (dried chips ground into flour and cooked into a thick porridge). Almost all processing is done by women at home or in specialized processing centers in rural areas.

Up until the early 1990s, cassava cultivation was mostly based on traditional low-yielding cultivars (with average yields of 7–10 t/ha) and manual processing. Since the early 2000s, many states in Nigeria have witnessed greater attention by different actors to the promotion of cassava as an industrial crop, with the objectives of diversifying farmers' incomes, enhancing foreign exchange earnings and increasing employment opportunities. This process was boosted further between 2002 and 2010 with the implementation of a Presidential Initiative that aimed at promoting cassava for the purposes of poverty alleviation and improved food security. The development of cassava markets in several states during this time enhanced the adoption of high-yielding cultivars, with on-farm yield potential up to 25 t/ha, resulting in increasing mechanization of labor-intensive processing stages (grating, pressing, roasting, drying, and milling). The impact of these developments was positive, although productivity in Nigeria (8.2 t/ha – FAOSTAT 2021) remains significantly below the potential. This highlights the need for further efforts to establish a sustainable system for delivering quality seed of high-yielding cassava varieties to farmers.

Brief history of cassava seed production initiatives in Nigeria In spite of the importance of the cassava crop for livelihoods in Nigeria, the seed system remains largely informal. Some of the key constraints include an insufficient and unsustainable supply of EGS, a poorly functioning national variety release system, policies that limit access to publicly develop improved varieties by private seed companies, and the widespread occurrence of seed in markets which is not true-to-type.

Formal plant breeding for cassava started in Nigeria in the 1970s, although there were few large-scale efforts to disseminate improved varieties until the early 2000s after which projects began to play the major role in cassava seed delivery (Okechukwu and Kumar 2016). Examples included the cassava mosaic disease (CMD) project from 2004 to 2007, the Cassava Enterprise Development Program

(CEDP) (2008–2010), the UPoCA Project (2008–2010), the CFC West Africa Project (2008–2012), and Cassava: Adding Value for Africa (CAVA) (2008–2019). These projects distributed disease-resistant varieties to farmers, who then distributed to community seed gardens, which multiplied seed for smallholders. Seed gardens and multiplication work were project-funded activities. None of these projects had a commercial focus for seed delivery, so as the projects came to an end, seed multiplication and dissemination also stopped.

The first project to attempt more formal commercialization of the cassava seed business was the sustainable cassava seed system (SCSS) project (2012–2015), which was the first to work with Village Seed Entrepreneurs (VSEs). From 2016, this approach was carried forward and expanded through the project entitled "Building an Economically Sustainable Integrated Cassava Seed System in Nigeria" (BASICS), managed by the CGIAR Research Program on Roots, Tubers, and Bananas (RTB). This was the first initiative in Nigeria to attempt to develop a comprehensive sustainable system for the supply of improved cassava seed. Some of the key partners in this work were NRCRI, NASC, IITA, Catholic Relief Services (CRS), Context Global Network (USA), and Fera Science Limited (UK). All partners worked with VSEs and private sector processing companies to commercialize cassava seed. By the time the grant to BASICS had come to an end in early 2020, significant progress had been made to build the breeder, foundation, and commercial seed levels necessary to create an economically sustainable seed system in Nigeria. But there were still kinks in the system and fragility in the new institutions. Most notably, efficient and practical EGS production approaches had not been established, the cassava seed regulatory system had just been implemented at pilot level, and there was very little geographical coverage of areas targeted by the sustainable seed production effort. Additionally, IITA and NRCRI had established two new private seed companies. These were GoSeed and Umudike Seeds, respectively, and were still in the early stages of becoming fully self-sustaining by the end of the BASICS project. In order to cement progress already achieved in building sustainable cassava seed systems, BMGF funded another phase – BASICS-2 – which aimed to strengthen the work in Nigeria and link it with similar activities in Tanzania (the BEST project) to consolidate the progress made to date, address the weaknesses, and begin the process of marketing this novel model to other governments and donors for replication.

The business case for commercial seed production, markets, and demand Prior to the implementation of the SCSS and the BASICS projects in Nigeria, the view was that very few farmers saw a business opportunity in cassava seed production. BASICS, building on the SCSS experience, showed that seed entrepreneurs can produce and sell certified seed of improved varieties, generating profits for both the seller and the buyer. The project documented the profitability of commercial seed production by the top 50% of the VSEs in different states in Nigeria. These VSEs in Benue State and South-South regions made average net profits of US$ 988 and US$ 551 per ha respectively (Table 15.1). Some VSEs in Benue State followed the ratooning strategy, and they obtained a net profit of US$ 1588 at the end of the two

Table 15.1 Average profitability of cassava commercial seed production by VSEs per ha in different regions of Nigeria. (Typical sale prices of cassavas stems/bundle: Foundation Seed US$ 2, Commercial Seed US$ 1–1.5, informal (roadside) unverified seed US$0.5–1, although prices vary by region and market demand)

Production costs (US$/ha)	VSEs Benue State	VSEs Abia, Imo, Akwa Ibom, and Cross Rivers States
Land (prevailing lease cost – actually paid or opportunity cost)	19	70
Seed (foundation seed – 100 bundles/ha)	153	114
Labor (planting, weeding, harvesting, etc.)	238	506
Inputs (including herbicides and other pesticides, fertilizer)	112	205
Miscellaneous (fuel, repairs, transport, utilities, certification, fees, etc.)	78	50
Total production costs (US$/ha)	600	945
Revenues		
Stem yield (bundles/ha)	300	412
Total revenue from stem sales (US$/ha)	566	916
Root yield (t/ha)	15	15
Total revenue from root sales (US$/ha)	1022	580
Total revenue (US$/ha)	1588	1496
Summary		
Total production cost (US$/ha)	600	945
Total revenue (US$/ha)	1588	1496
Net profit (US$/ha)	988	551

seasons. Most of the entrepreneurs sold their cassava stems at the farm gate, followed by sales at the local market; little seed reached distant markets.

Both the VSEs and the cassava varieties they were producing needed to be promoted via various channels including demo plots alongside main roads in various locations, market day promotions, advertisements in banners and flyers in local languages, radio spots, and a public service call-in system that provided free, on-demand information. As these were supported through the BASICS project, going forward, such commercialization activities and costs need to be incorporated into the business plan of the seed companies and farmer associations selling certified seed. In addition, a website (www.cassavastems.com) was launched providing information about the project, the VSEs with their location and contact details, as well as the varieties available.

A review of the more successful VSEs showed that the viability of commercial seed production is enhanced when the producer can dedicate larger areas for production (>1 ha) and that smaller VSEs need to be organized into an association that can support training, access to inputs, and markets by bringing in economies of scale. Moreover, a survey of 218 cassava farmers who bought certified seed from VSEs in 2017–2019 showed that the main reason for buying stems was to access new varieties and to be sure of their identity. These criteria were considered much

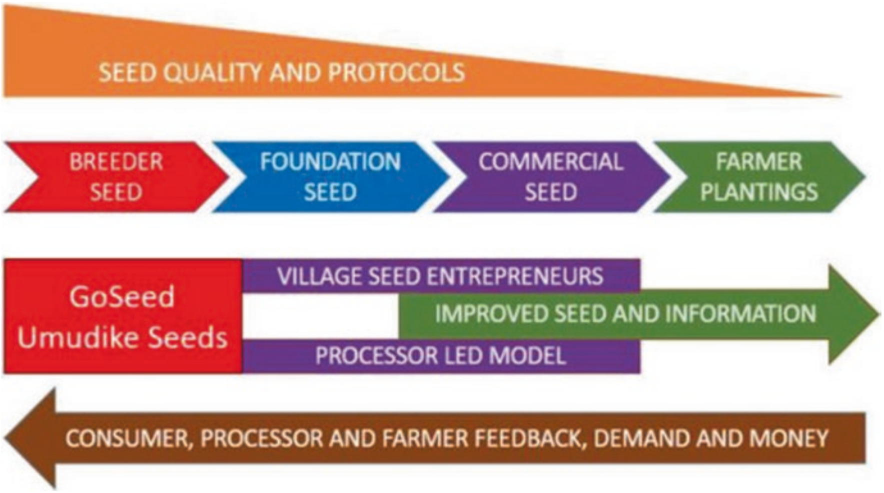

Fig. 15.2 Integrated approach for the seed value chain

more important than the state of health of the certified material. Nevertheless, NASC certification did mean that the VSEs' trustworthiness and prestige was enhanced. It was observed early on that women VSEs face more challenges in accessing credit and inputs. Consequently, the BASICS project placed a special focus on building capacity and promoting social capital and networking among female seed entrepreneurs.

Approaches to achieving a sustainable supply of quality seed Through the SCSS and BASICS projects in Nigeria, a sustainable supply of quality EGS and certified seed was established following different approaches. The integrated value chain approach that this encompasses is illustrated in Fig. 15.2.

(i) *EGS system*: An adequate and reliable supply of healthy and virus-free breeder and foundation seed of improved varieties is the starting point for a sustainable seed system. IITA and NRCRI in Nigeria are the mandated institutions for these seed sources. In a pioneering intervention, the BASICS project helped IITA and NRCRI establish the private limited companies, GoSeed and Umudike Seeds, respectively. These companies produce and sell EGS of improved varieties on a commercial basis. With the assistance of Sahel Consulting Agriculture and Nutrition Ltd (Sahel), financially viable business plans were developed for both these entities, and they started implementing the plans in 2019. GoSeed has established a network of contract farmers to produce breeder and foundation seed, to increase capacity and expand the geographic reach of EGS. Both companies certify their seed through NASC following updated certification protocols, ensuring seed health as well as varietal identity. Foundation seed is sold to commercial seed producers, and the companies are now expanding their commercialization efforts by promoting new improved varieties. GoSeed and Umudike Seeds are linked to the breeding programs of IITA and NRCRI, and as new varieties are tested with farmers and processors, end user experiences and requirements for improvements are fed back to the breeding programs. These two companies are also expanding marketing activities to promote the improved varieties and certified seed.

(ii) *Certified seed system*: Certified seed is produced from foundation seed and can be multiplied through ratooning a maximum of three times by certified seed producers, subject to approvals by NASC inspectors. Certification occurs at breeder seed, foundation seed, and certified seed levels. Certification standards at the highest levels of EGS production are the most stringent, as these impact the entire seed system at national level. Standards at VSE level are more lenient to ensure that seed producers at this level succeed but also so that the inspections are affordable. Cassava farmers purchase certified seed for root production. Every planting season, there is a large demand for planting material. Traditionally, this has been met by farmers' own saved seed; from friends, family and neighbors; through dissemination campaigns from governments and projects; via informal markets; or from formal markets (Pircher et al. 2019). The formal seed market is almost negligible. According to a NASC Annual Report in 2017, only 117,722 bundles (0.0003% of the total cassava seed market) of certified cassava seed were produced and sold. Given this situation, the BASICS project developed two models of certified seed production: the village seed entrepreneur (VSE) model and the processor-led model (PLM), described below. The initial scaling target of the certified seed system is to meet 2% of the cassava seed requirement for Nigeria, which would be equivalent to 5–10% of the nation's formal seed production.

(iii) *VSE model*: The project selected farmers, both young and old, men and women, trained them on cassava agronomy, quality assurance for meeting certification requirements, and business aspects of the seed business. VSEs were selected according to nine criteria, mostly relating to experience of agriculture as a business and willingness to adopt innovations. Criteria relating to assets were relaxed for women farmers to avoid structural bias. Approximately 30% of the VSEs were women. Responding to the demand for improved varieties in their vicinity, the VSEs grew these varieties and marketed them to farmers nearby. In order to enhance sustainability, the project organized the VSEs into a network that continued the training and promotion of the member VSEs as well as marketing of new improved varieties. The profit motive for such seed entrepreneurs ensures sustainability.

(iv) *PLM*: Traditionally cassava processors bought the roots needed for their factories in open markets, and this meant that they got a mixture of varieties, mostly local varieties, thus potentially reducing the factory's profitability as well as not fully meeting the processing demands for particular quality traits in the roots. The BASICS project selected cassava processors who demonstrated a strong interest in piloting the PLM model and developing business-oriented systems of seed dissemination. The best varieties for each processor were identified by setting up demonstration trials at the processor sites and processing the roots in their factory. The seed of these varieties was then supplied to a network of cassava outgrowers linked to the processor, with a root buyback agreement. In this manner, the PLM model looks to have the farmers benefit from the higher yields obtained from certified seed of improved varieties along with a guaranteed market. The processors benefit from getting an assured quantity and quality of cassava roots for processing. The increased net profitability ensures the sustainability of the PLM.

New varieties delivered and technologies established to increase the volume and efficiency in the supply of high-quality seed Through collaboration between the NextGen and BASICS projects, five new varieties were released in Nigeria in 2020. NextGen is a BMGF-funded project which aims to modernize cassava breeding in Africa using cutting-edge tools. All five varieties were targeted to meet the product profiles for the country which range from industrial applications, primarily high-quality cassava flour (HQCF) and starch, to fresh roots, gari, and fufu. Varieties with different optimal end uses were promoted using a market segmentation approach (e.g., each variety was marketed to the customers most likely to use it). In addition, a naming event was organized to rename the varieties from conventional breeding code names (mostly made up of numbers and easy to forget), to more farmer-friendly names. The renaming of the varieties was a strategy aimed at enhancing the promotion and delivery of the new varieties to farmers. Historically, when new varieties are released, it can take several years of field multiplication before the variety reaches grassroots farming communities. Difficulties experienced in accessing planting materials of new varieties can discourage farmers from cultivating them. Novel rapid multiplication techniques, such as SAH, combined with improved systems for the rapid dissemination of cassava seed, have given farmers much faster access to the new varieties. This has been further enhanced by establishing the EGS companies – IITA GoSeed and Umudike Seeds – and farmers can now access seed of new varieties within 2–3 years of their initial release. The EGS companies in addition to the production and commercialization of the varieties are also helping independent seed producers across the country increase the production of foundation seed. This will bolster sustainability of seed demand and supply of cassava seed in a structured manner.

Assuring the quality of cassava seed from breeder seed to community level NASC is the government agency responsible for regulating the production, marketing, and trade of seed in Nigeria, as well as for implementing national seed policy and regulations. NASC has adopted a three-tier system for cassava seed production, comprising breeder seed (BS), foundation seed (FS), and certified seed (CS). Cassava seed quality assurance involves control of the generations of seed and seed quality, as defined by its genetic purity and health status. BS is the first seed generation produced under the supervision of plant breeders, and FS is the progeny of BS, and both may be recycled twice. CS may be multiplied three times. The quality parameters considered during each cycle include genetic purity, isolation distance, field management (weediness), and incidences of notified pests and diseases which must

Table 15.2 Maximum pest and disease thresholds for Nuclear Seed (NS), BS, FS, and CS for cassava in Nigeria

Parameter	Maximum threshold			
	NS	BS	FS	CS
Off type	0	0%	≤3%	≤5%
[2]Cassava mosaic disease	0	0%	≤2%	≤2%
[1]Cassava anthracnose disease	0	≤3	≤3	≤3
[1]Cassava bacterial blight	0	≤3	≤3	≤3
[2]Scale insects and termites	0	≤5%	≤5%	≤10%
[1]Cassava mealybug	0	≤3	≤3	≤3
[1]Cassava green mite	0	≤3	≤3	≤3
[1]Cassava white or brown spot	0	≤3	≤3	≤3
Minimum isolation distance 3 m for BS, FS and CS; not applicable for NS				
At least 7 months old for stem harvesting (stem girth of 1.5 to 2.5 cm)				
About 1 m stems; 50 stems per bundle				
No recycling limit for NS, two generations for BS and FS, and three generations for CS				

[1]Mean severity score per field (using a 1–5 scale ranging from 1 = no symptoms to 5 = very severe)
[2]Percent incidence

be lower than tolerance levels set for each class (Table 15.2). If seed does not meet the required standards, it is rejected and cannot be sold as certified seed.

This system for cassava seed certification functions effectively in Nigeria, although the limited supply of tissue culture material to start the process has been a bottleneck. The adoption of SAH since 2016 helped to address this situation. In addition, a new NASC-approved seed class (nuclear seed, NS) was recently added. NS is produced from TC or SAH material and is used as the source for BS. NS seed is not limited by seed cycle, as long as the planting material remains genetically pure and true-to-type, and the material remains entirely free of notified pests and diseases.

As some VSEs do not meet all of the eligibility requirements for CS production, NASC allows them to be registered and produce CS seed as Community Seed Producers.

NASC organizes a minimum of three inspections. The first is prior to field establishment to verify seed source and field site. The second is 3–4 months after planting, and the third inspection is at the time of harvest. NASC may propose additional inspection visits, as well as the collection of samples – especially from EGS fields for testing of cassava mosaic viruses, which are endemic in Nigeria. Viruses that cause CBSD are not known to occur in Nigeria; however, NASC, IITA, and cassava stakeholders have prioritized CBSD prevention since this disease poses a major threat to cassava production in Nigeria. NASC has therefore established facilities for testing for cassava brown streak viruses and has trained inspectors in recognizing symptoms and how to respond in case the disease is introduced to the country.

Due to the limited number of seed certification officers, timely certification has been a bottleneck. To overcome this challenge, NASC introduced the use of "licensed seed inspectors (LSIs)" who are third party agents trained and approved to perform CS field inspection and to collect samples for testing under NASC supervision. Forty LSIs from four Nigerian states were commissioned in 2020.

To enhance seed quality compliance and enable e-seed certification, NASC adopted Seed Tracker in 2019 as the official e-certification tool for cassava. This ICT application has been tailored to NASC seed regulations to enable seed producer registration, seed field registration, inspections, digital data collection, and issuance of certificates and labels for eligible producers and seed fields.

Alternative "light touch" quality assurance models have been proposed for cassava seed systems in Nigeria that maintain certification-oriented measures for EGS but which recommend less regulation for community-level seed production and a primary focus on the delivery of seed of new varieties with known provenance (Wossen et al. 2020).

15.3.2 Building an Economically Sustainable Seed System for Cassava in Tanzania (BEST)

The context. Cassava in Tanzania in the 2000s Tanzania is the fifth largest cassava producer in Africa, with an annual production for 2019 of nearly 8.2 million tons (FAOSTAT 2021). Although yields declined from 1997 (8.6 t/ha) to 2015 (5.4 t/ha), largely due to CMD and CBSD epidemics, they have subsequently recovered – reaching 8.3 t/ha in the latest year for which data are available (2019). The 2002–2003 National Sample Census of Agriculture indicated that 24% of Tanzanian farmers grow cassava and that the production is concentrated in the southeast and northwestern parts of the country. Most farmers market only a small proportion of their output, although there are a relatively small number of medium- and large-scale farmers who sell most of their harvest. In Mtwara, the region in Tanzania that is most dependent on cassava, only 17% of the output is marketed. More fresh cassava might be sold if the roots were not so perishable. Cassava in Tanzania was heavily impacted by the severe CMD pandemic which spread through northwestern production zones from 1998 to 2010 (Legg 1999, 2010), compounded by outbreaks of CBSD in the same areas from 2006 to the present day (2022). In view of the current importance of cassava in Tanzania, any reduction in productivity arising from a disease or pest outbreak can lead to decreased food security, reduced incomes, higher food prices, and subsequently to social tension. To tackle emerging disease and pest attacks, farmers need access to high-quality seed of newly developed varieties with multiple pest and disease resistance. This highlights the particular importance of "clean seed" systems in Tanzania.

Brief history of cassava seed production initiatives in Tanzania Cassava seed systems have been functioning in an informal way ever since the crop was introduced to Tanzania. Seed exchange among farmers across villages, towns, and even countries in the region is a normal practice in the informal seed system. Most cuttings are obtained from friends, relatives, or neighbors without payment. Some in-kind sales have also occurred in addition to free exchange. In the informal seed system farmers may select seed from vigorous plants in their own fields or obtain seed of favored varieties from trusted sources, but there is no systematic approach to managing quality. Although informal approaches may work under normal circumstances, they can often result in rapid and widespread declines in productivity where cassava is affected by diseases such as CMD and CBSD, which are readily propagated through stem cuttings.

It has been estimated that less than 2% of cassava planting material in Tanzania is quality seed (AGRA 2016), although the current proportion of certified planting material by 2022 may be less than 1%. Previously, between 1995 and 2000, the Southern Africa Root Crops Research Network (SARRNET) introduced a semiformal, three-tier seed multiplication scheme. Cassava was multiplied at primary, secondary, and tertiary levels. At the primary level, the sites were at or near research stations for easy supervision and monitoring by scientists. At the secondary level, the sites were established and managed by extension staff, NGOs, faith-based groups, and some individual farmers. Tertiary multiplication sites were mainly smaller, more numerous, and managed by farmers but usually backstopped by scientists, extension staff, or NGOs.

From 2007 to 2012, the BMGF-funded Great Lakes Cassava Initiative (GLCI) project operated across six countries in East and Central Africa including Tanzania (Walsh 2016). The project brought together national and international research, government, and nongovernmental organizations in a single network tasked with producing and delivering disease-tolerant cassava seed to 1.15 million smallholder farming families. GLCI partners collectively learned and applied four innovative seed system approaches: (1) decentralized production and dissemination, (2) quality management protocols, (3) targeted dissemination and traceability in the seed system, and (4) disease surveillance, including source site field testing with virus diagnostics to control CBSD spread. This semiformal seed dissemination system promoted quality of seed but was not formally administered by government regulatory institutions.

In 2014, TARI piloted public private partnerships in cassava seed systems. Two private companies – Aminata seed company and CBS Arusha – were involved in producing basic seed and TC plantlets respectively. TARI piloted pre-basic, field-based seed production at the station for closer supervision. From 2012 to 2017, scientists from IITA, TARI, and the Mennonite Economic Development Associates (MEDA) increased their efforts to advocate for a commercialized, clean (healthy) cassava seed system and implemented several projects to address this challenge. Currently, there is a strong pipeline of formally released superior varieties that flow into an organized seed system with registered cassava seed entrepreneurs, where quality is controlled by seed inspectors through a legally enforced but producer-friendly seed certification process. Moreover, the Government of Tanzania is providing strong policy-level support for the modernized seed system as part of its overall National Cassava Development Strategy which was officially launched in 2021 (IITA 2021).

The business case for commercial seed production, markets, and demand Demand for cassava seed production comes from farmers who are growing cassava roots that they consume or sell to markets. The market in Tanzania comes primarily from home consumption and fresh root sales. Increasingly, commercial markets are developing with small-scale HQCF production and, more recently, with larger-scale investments being made into flour and starch production and even nascent opportunities with industrial applications such as ethanol production and export of dried cassava. The Tanzanian demand is amplified by the high disease pressure of CMD and CBSD which dramatically reduces farm productivity and increases the farmers' need for improved, disease-resistant, and high-yielding varieties. The commercial cassava seed system is the mechanism for these farmers to access the improved varieties that have been released by the government.

The commercial seed production model based on cassava seed entrepreneurs (CSEs) distributed in a hub-and-spoke model with quality control oversight is a profitable and sustainable model to reach cassava seed farmers. The development of the models in the BEST Cassava project has demonstrated that farmers are willing to pay for improved cassava seed that has been certified. The average profitability of CSEs from 2018 to 2020 ranged from US$1000 to 1500 per ha which demonstrates a positive business case, and it is a key indicator for a commercially sustainable seed system. Farmer business associations have been set up to support CSE networks with the aim of gradually taking over training and support functions which are currently being delivered through the BEST Project. In addition, the Tanzania Cassava Producers and Processors Association (TACAPPA) is a newly created independent organization which aims to provide long-term advocacy and support for cassava farmers, processors, and traders, including CSEs. This and allied government initiatives to foster the commercial development of cassava in Tanzania are providing a strong business-oriented environment which will enhance the sustainability of the emerging cassava seed system.

Approaches to achieving a sustainable supply of quality seed The cassava seed system in Tanzania was developed using a formal, commercialized approach that factors in quality assurance and profitability for the CSEs to ensure a cost-effective and sustainable system. Since cassava seed is bulky and perishable to transport, the BEST Cassava project has developed the seed system based on a hub-and-spoke model to foster effective seed delivery. It includes a smaller number of pre-basic (equivalent to BS) and basic (equivalent to FS) CSEs, who then sell cassava seed in subsequent steps to certified and quality declared seed (QDS) CSEs who ultimately sell to root producing farmers (Fig. 15.3). Cultural norms and traditional patterns of land ownership mean that there have been difficulties in encouraging gender balance among CSEs. Currently women comprise about 30% of CSEs, although the proportion is higher at the community level and lower among basic seed producers. Under the follow-on BASICS-2 project, however, there are twin goals to nearly double the

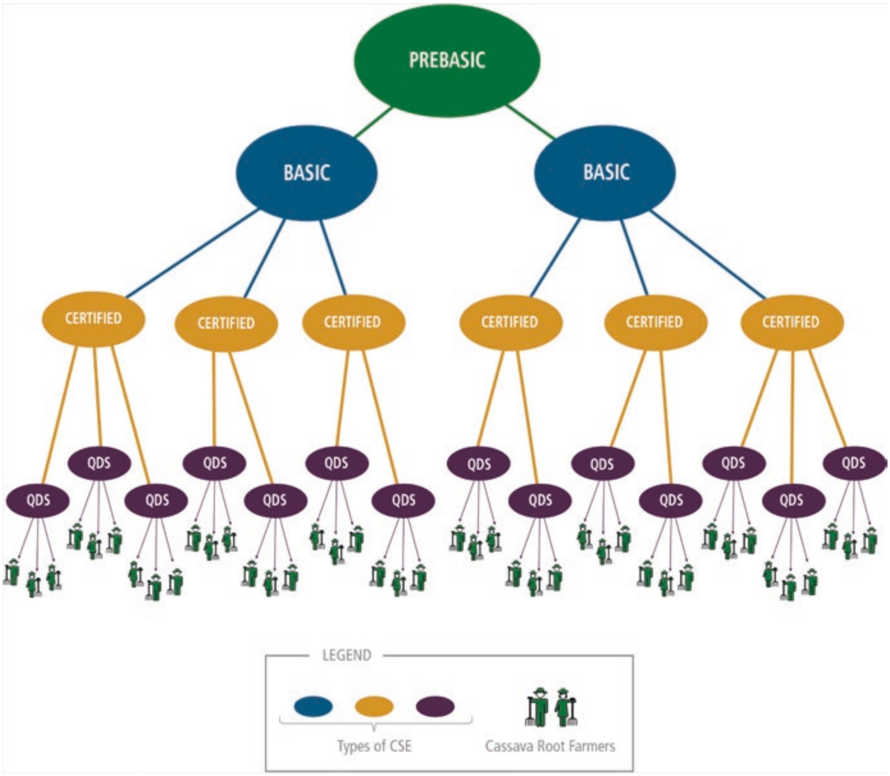

Fig. 15.3 Hub-and-spoke model of the commercialized cassava seed system in Tanzania. CSE - cassava seed entrepreneur, QDS - quality declared seed

number of CSEs while at the same time increasing representation of women to 50% of the total.

(i) *Pre-basic/basic seed*. The production of pre-basic seed in Tanzania is overseen by TARI. The role of this level is to produce initial seed stock of the released varieties that will then feed into the commercial seed system for distribution. The original model for pre-basic seed production was to take small amounts of lab-tested, virus-free stock from tissue culture, harden it off in a screenhouse, plant it in the field for one cycle of field multiplication, and sell mature cassava cuttings to basic CSEs who would then multiply one more cycle of seed and sell it to the next level – certified CSEs. This model is evolving with more advanced techniques being used at both the pre-basic and basic levels to increase the capacity and production. Pre-basic producers now use a "two-node" rapid multiplication step in the screenhouse and aim to incorporate SAH capability. Basic CSEs are also developing their own screenhouse capability for "two-node" rapid multiplication.

(ii) *Certified seed*. Certified CSEs purchase basic seed as their input and multiply a cycle of seed in the field before they sell to QDS CSEs. To maximize profitability of the model, certified CSEs vary ratooning strategies and planting densities (within the parameters laid out in the Tanzania certification protocols) to optimize their stem production. They also sell roots to supplement stem sales either using a piecemeal root harvest strategy or selling all the roots at the end of their ratooning cycle when it is time to refresh their fields with new basic seed stock.

(iii) *QDS seed*. QDS producers sell both their stem harvest to farmers and their root harvest to the market. To gain certification, QDS CSEs are inspected by decentralized ASIs who have been gazetted by TOSCI. The QDS CSEs also have the least stringent certification requirements of any level in the seed system. QDS producers plant at an optimum spacing for root production (1 m × 1 m) rather than for stem yield. Their farming strategy is driven more by root yield than by stem production.

(iv) *CSE business associations*. Business associations made up of CSE members have been formally organized and registered as legal entities in Tanzania. The role of these business associations is to support the CSEs in multiple aspects of making the CSE businesses sustainable such as registering their business, training on good agricultural practices, providing access to finance through a revolving loan fund, and marketing their products.

New varieties delivered and technologies established to increase the volume and efficiency in the supply of high-quality seed Tanzanian researchers have officially released 26 improved cassava varieties that are high-yielding, have high dry matter content, and that are tolerant to CMD and CBSD. Most of the new released varieties are not known by farmers, and it may take up to 10 years for a new variety to become popular. For example, variety Kiroba was officially released in 2004 but only became popular after 10 years. TARI has therefore collaborated with partners such as IITA, MEDA, and farmers' associations in efforts to promote new varieties through demonstration plots, farmer field days, seed fairs, annual agricultural shows, and TARI agribusiness expo events organized at research centers. As part of this effort, 109 plots to demonstrate released varieties were established in 2020 in the Lake Zone (30), Eastern Zone (61), Southern Zone (17), and Central Zone (1). Most of the varieties were selected primarily for yield and virus disease resistance, although they have diverse processing qualities. Targeting specific varieties for particular output markets as part of a market segmentation strategy is an important future objective of cassava value chain stakeholders in Tanzania.

Technologies that have been implemented in Tanzania to increase the volume and efficiency in the early stages of multiplication include tissue culture, mini-cuttings, the pencil stem technique, and SAH which has been piloted by a private company, KilimOrgano. TARI has implemented the use of mini-cuttings and the pencil stem technique for rapid propagation of new varieties. Stems are allowed to grow from hardened TC plantlets for about 8 weeks under screenhouse conditions.

Green mini-cuttings are then harvested to establish new plants under controlled conditions. With this method 1 plantlet can give up to 300 plants in 6 months.

Assuring the quality of cassava seed from pre-basic to community level Seed quality in Tanzania is controlled by TOSCI. As in Nigeria and elsewhere, the two primary considerations during seed quality inspections are the genetic purity of the material and the restriction of pest and disease incidences to within prescribed tolerance levels. Four seed classes are recognized under the Seed Act of the Government of Tanzania. These are pre-basic (PB), basic (B), certified (C), and quality declared seed (QDS). TOSCI inspects all PB, B, and C fields on at least two occasions and is mandated to inspect at least 10% of QDS fields twice. In view of the small number of trained TOSCI seed inspectors relative to the size of the country, a selected group of extension officers has been trained to conduct QDS inspections on behalf of TOSCI as ASIs. By the end of 2021, there were 130 officially gazetted ASIs in Tanzania.

Field inspections have traditionally been documented by filling out paper forms. Since 2020, however, inspectors have been able to conduct certification assessments digitally using tablets and the Seed Tracker platform. During assessment, 200 plants are examined in each of 5 quadrants of 40 plants for each hectare. The presence of major pests and diseases is scored (Table 15.3), either on the basis of the percentage of symptomatic plants or the average severity, which is assessed using a one to five scale in which one is unaffected and five is very severely affected. The two most significant differences in certification systems in Tanzania and Nigeria both arise from the greater importance of the virus diseases (CMD and CBSD) in Tanzania than in Nigeria. Required isolation distances are much greater in Tanzania (50 m to 300 m) than in Nigeria (3 meters), while tolerance levels for CMD are less

Table 15.3 Maximum pest and disease thresholds for PB, B, CS, and QDS for cassava in Tanzania

	Maximum threshold			
Parameter	PB	B	CS	QDS
Off type	0	0%	1%	1%
Minimum isolation distance	300 m	200 m	100 m	50 m
[1]Cassava mosaic disease	1%	2%	3%	10%
[1]Cassava brown streak disease	2%	4%	7%	10%
[2]Cassava bacterial blight	2.5	2.5	2.5	3.5
[1]Scale insects and termites	1%	2%	4%	8%
[1]Cassava mealybug	1	2%	4%	8%
[2]Cassava green mite	2.5	3.0	3.5	3.5
Harvest age (new crop: 8–18 months; ratoon crop 6–12 months)				
Minimum cutting sizes (length: 20 cm; girth: 2 cm; nodes: 5)				
Maximum ratoons (PB, B, CS: 2; QDS: 1); Maximum shoots per ratoon: 3				
Minimum number of inspections: 2				

[1]Percent incidence

[2]Mean severity score per field (using a 1–5 scale ranging from 1 = no symptoms to 5 = very severe)

restrictive in Tanzania (3% at CS level) than they are in Nigeria (≤2% at the equivalent CS level).

Virus testing is only required for PB seed production where the sampling protocol provides for the testing of 2% of plantlets. Testing is only done for cassava brown streak viruses, and this is conducted by TOSCI using a real-time PCR protocol (Adams et al. 2013). PB producers pay TOSCI for this testing, and the charges are incorporated into the PB business plans and are factored into the price of the PB seed. Recent work has focused on the development of LAMP protocols for virus testing that will be cheaper and quicker and which will have the potential to be run in a decentralized network of less well-equipped laboratories.

Tanzania continues to strengthen its cassava seed system, and there are plans for the period 2022–2025 to increase the number of CSEs to more than 1000. The decentralized seed certification system that is being established should offer sustainable capacity to maintain the quality of seed produced through this system while at the same time improving the awareness of the importance of seed quality among all actors in the cassava sub-sector in the country.

15.4 Key Lessons Learned and Future Opportunities

Coordinated cassava seed multiplication initiatives have been running in many of the major cassava-producing countries of Africa for several decades. It is only in recent years, however, that more attention has been directed at establishing sustainable and commercially oriented seed systems for cassava. The largest initiatives of this type, described in this chapter, have been the BASICS project in Nigeria and the BEST project in Tanzania. Both have provided valuable lessons about the potential viability of business-focused cassava seed systems, and some of the key issues that have emerged are as follows:

15.4.1 Lessons Learned

(i) *Farmers are willing to buy seed*. Results from Tanzania in particular have demonstrated that there is a strong demand for high-quality cassava seed. In the early years of the BEST project, there was a greater reliance on selling to institutional buyers such as government district authorities or NGOs, but by 2020 more than 80% of certified cassava seed was being sold to individual farmers.

(ii) *Demand drivers differ*. Smallholder producers are willing to pay for certified stems of desired varieties, but the drivers of this demand differ between regions and countries. In Nigeria, farmers buy cassava stems mainly to obtain new varieties, with strong implications for seed enterprises throughout the value chain. In Tanzania, by contrast, the main driver for seed demand is the health status of the material, as virus diseases affect a large proportion of stems obtained from uncertified material of local varieties. Studies of repeat purchases of cassava seed are required, however, to confirm that accessing a new variety (in Nigeria) or managing disease (in Tanzania) will not curtail business opportunities for seed producers.

(iii) *Cassava seed is a viable business under the right conditions*. Data from both Nigeria and Tanzania have confirmed that it can be profitable to produce and sell certified cassava seed of improved varieties. In Nigeria, the larger VSEs in particular are profitable, particularly those who also sell roots. However, without new varieties, the lack of a clear yield premium for certified seed undercuts the business case for VSEs, making it much more challenging to create a sustainable business than in Tanzania. In Tanzania, combining roots sales with stem production has also been shown to be a key to success for CSEs, and profitability has increased gradually from 2018 to 2020.

(iv) *There are major limitations to the scaling of the VSE model in Nigeria because of the high setup and support costs*. Establishing networks of cassava seed producers requires significant start-up investments, which can limit the potential for scaling. Several options are being explored to overcome this challenge, including creating an apex organization for VSEs, and moving to much larger VSEs.

(v) *Improved private sector engagement will improve long-term viability*. Involving cassava processing companies as facilitators of the commercial seed system warrants further investigation as these enterprises are the ultimate beneficiaries of the system and investments from them may offset expenditures that might otherwise be borne by projects or governments.

(vi) *New varieties*. An efficient and productive breeding pipeline is required to ensure that new varieties become available to cassava seed producers on a regular basis. Stronger linkages with new varietal development in breeding are essential. Demand creation trials can help to identify the most suitable varieties for processors to scale out via their outgrowers. An essential part of the seed value chain is naming varieties and promoting them to highlight their specific uses and production conditions.

(vii) *Modern tools for rapid multiplication*. EGS production needs to apply modern multiplication technologies to increase the speed of dissemination of new varieties. This has been achieved through the use of tissue culture, screenhouse-based mini-cutting multiplication, and SAH. SAH labs can produce hundreds of thousands of plantlets and allow for real-time inventory management. The technique enables the rapid multiplication of promising new varieties in response to market demand. Processors in Nigeria showed an interest in investing in cassava seed units for backward integration to provide stems of varieties of interest to their own enterprises and for outgrowers. Valuable progress was made in the adaptation of SAH by processors, but the commercial case for this still needs to be comprehensively made.

(viii) *Spin-off companies for EGS production*. In Nigeria, GoSeed and Umudike Seeds were established as spin-off companies from IITA and NRCRI, respectively, and have got off to a promising start. Both have played an effective role in producing EGS seed on a commercial basis. A similar approach has also been taken by TARI in Tanzania. These spin-off companies have the potential to play an important role in linking breeders with commercial seed producers; however, it will be essential that they are run with an entirely commercial mindset separated from the research function.

(ix) *Organization of VSEs/CSEs*. Community-level VSEs/CSEs can benefit from being organized into associations which can provide support with finance, training, and quality assurance. The seed entrepreneurs require extensive training both in seed production and business practices. This can be done sustainably by organizing them into large networks, where participation in the network for a fee can allow the network to provide the needed services. This needs to be accompanied by marketing campaigns using different strategies to promote the new varieties, create awareness of the benefits of certified seed, and publicize the seed entrepreneurs.

(x) *Quality management programs are required to facilitate commercial seed systems*. Two of the most important requirements for farmers buying cassava seed are that the variety is known and that the stem cuttings are of high quality. Cassava seed quality assurance systems established in Tanzania and Nigeria have shown that certification systems can facilitate effective trade in cassava seed. However, these systems need to be tailored to the local environment. Where disease is less important, such as in Nigeria, inspections at community level need to be cheap and pragmatic enough to enable seed businesses to flourish. Where disease is more important, as in Tanzania, effective quality control is required down to QDS level, although decentralized inspection systems should be affordable and have quality standards that are realistically achievable. CSE/VSE associations can play an important role in facilitating cassava seed quality management at community level.

(xi) *Digital tools such as Seed Tracker can greatly enhance the efficiency of the seed system and support M&E*. Seed Tracker has proven to be highly effective in increasing the efficiency of the cassava seed certification work of TOSCI and NASC. In addition to permitting e-certification and remote registration of seed producers, the platform promotes the seed businesses of its users and allows the seed regulatory agencies to track performance throughout the system in real time.

(xii) *There are important scaling constraints that need to be defined* (Sartas et al. 2020). Currently, the formal cassava seed systems established in both Nigeria and Tanzania each produce less than 1% of the national requirements for cassava seed. Although seed producers have been able to successfully sell to local root producers, establishing a network of commercial cassava seed producers is relatively slow and expensive, requiring significant training. This is likely to be a key constraint in scaling commercial cassava seed systems, both in countries where there are established systems as well as in places where systems would need to be set up from scratch. Experience from other work on RTB crops conducted by the CGIAR demonstrates that the application of scaling readiness analyses will help to identify scaling bottlenecks and enhance the impacts of commercial cassava seed systems. A key constraint for scaling to other countries is the investment needed to establish practical and affordable certification systems and a network of seed entrepreneurs at the various levels of the system. Teams focused on scaling the commercial cassava seed system models described here will need to specify and quantify these costs.

Significant investments have been made in modernizing and building sustainable models for cassava seed systems in Africa over the last decade. Contrary to the widespread perception, cassava seed is extensively traded. Furthermore, newly established smallholder seed entrepreneurs have been successful in generating profits from cassava seed businesses. Although the factors driving demand for seed differ in different contexts (disease-resistant varieties in East Africa versus high-yielding varieties in West Africa), successes being achieved provide considerable hope for the successful scaling of approaches described in this chapter to other parts of Africa where cassava is an increasingly important climate resilient crop.

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