Inventory of novel approaches to seed quality assurance mechanisms for vegetatively propagated crops (VPCs) in seven African countries

Research Report
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CIP INTERNATIONAL POTATO CENTER

CGIAR

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for International Institute of Tropical Agriculture (IITA) and International Potato Center (CIP)

This paper presents findings from action research conducted as part of the Integrated Seed Sector Development in Africa Programme (ISSD Africa).

Cover photo: Virus testing using LAMP tool in Tanzania for sweetpotato.
Credit: K. Ogero, CIP

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LIST OF ACRONYMS

AFSTA	African Seed Trade Association
AIQCQA	Agricultural Inputs Quality Control and Quarantine Authorities
ATA	Agricultural Transformation Agency (Ethiopia)
BASICS	Building an Economically Sustainable Integrated Cassava Seed System in Nigeria
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
COMESA	Common Market for Eastern and Southern Africa
CSPMAE	Clean seed potato multiplication agri-enterprise (Kenya)
DVM	Decentralised vine multiplier
ECOWAS	Economic Community of West African States
EIAR	Ethiopian Institute of Agricultural Research
ESE	Ethiopian Seed Enterprise
FBSMS	Farmer-b Based Seed Multiplication Scheme
IITA	International Institute of Tropical Agriculture
ISF	International Seed Federation
ISSD	Integrated Seed Sector Development
IPR	Intellectual property right
KEPHIS	Kenya Plant Health Inspectorate Service
LAMP	Loop-mediated isothermal amplification
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries (Uganda)
NASC	National Agricultural Seed Council (Nigeria)
NDA	National Designated Authority
NSCS	National Seed Certification Services (Uganda?))
OFSP	Orange-fleshed sweetpotato
PS	Positive selection
QDS	Quality declared seed
RMTs	Rapid multiplication techniques
SADC	Southern Africa Development Community
SCCI	Seed Control and Certification Institute (Zambia)
SEEDAN	Seed Entrepreneurs' Association of Nigeria
SQA	Seed quality assurance
STAK	Seed Traders Association of Kenya
STAM	Seed Trade Association of Malawi
STTS	Seed Tracking and Traceability System (Uganda)
TASTA	Tanzania Seed Trade Association
TOSCI	Tanzania Official Seed Certification Institute
UPHI	Uganda Plant Health and Inspectorate Agency
USTA	Uganda Seed Trade Association
VPC	Vegetatively propagated crop
YIIFSWA	Yam Improvement for Income and Food Security in West Africa
ZASTA	Zambia Seed Trade Association

ABSTRACT

This paper provides an inventory of novel approaches to and mechanisms for quality assurance of the seeds of vegetatively produced crops (VPCs). It explores to what extent seven African countries (Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda and Zambia) are decentralising and integrating VPC seed systems, in terms of regulations governing the sector, methods of seed production, and methods of seed inspection and certification. It consolidates existing data and presents new data on decentralised seed quality assurance (SQA) approaches for VPCs in these seven selected countries. It makes relevant information readily available for policy dialogue on appropriate and inclusive SQA approaches, by providing an assessment of (i) the extent to which SQA has been decentralised, i.e., the extent to which third-party accredited inspectors have been deployed; (ii) countries' use of e-certification platforms; (iii) the involvement of seed producer groups and cooperatives in SQA; and (iv) any novel approaches to disease diagnostics or other relevant aspects of SQA.

The paper uses different, appropriately sequenced methods to ensure the different methods complement each other to offset the disadvantages of each method. These include a comprehensive literature review, an online survey, and key informants' virtual interviews. These are complemented by expert interviews, especially with both IITA and CIP experts based in Tanzania, Uganda, and Ethiopia plus one CIP expert with overall knowledge of the project countries in Africa.

Based on an online survey completed by officials from regulatory agencies from eight countries, and follow-up interviews with seed certification officials and researchers in the seed sector, the paper finds that almost all studied countries have some sort of decentralised seed production system in place, allowing large-scale companies, medium-semi-commercial companies and small holder farmers opportunities to produce both quality declared and certified seeds. These decentralised seed production systems may be regarded as novel, in that they deviate from the standard seed system practices proposed at international level, which focus on enforcing certified seed production. Further, the novelty is based on different countries adopting different processes because of different local constraints and different government/political structures. Such novelty is necessary in the African context of, *inter alia,* poor infrastructure for transporting VPC seeds long distance and limited technical skills for certifying seed. The innovative approaches chosen by these African countries are suitable for VPC seeds like those of cassava, sweetpotato, bananas, yams and potato – all of which have bulky and perishable planting materials.

The paper shows that it is possible to make decentralised VPC seed systems a reality in the right circumstances, and that in some cases countries have already made strides in doing so. However, several gaps exist in different countries, all of which need to be addressed. They include problems such as (i) legislation and regulations not specifically considering the quality assurance requirements of VPCs; (ii) shortages of trained staff throughout the system, but especially in far-flung areas; (iii) unavailable or inadequate training materials and handbooks; (iv) inadequate resources at local level, including support for inspection equipment and resources (e.g., vehicles); (v) poor monitoring and administration capacity in farmers' cooperatives/associations; and (vi) poor consideration given to gender empowerment. Each of these and other issues are discussed throughout the report and in the recommendations at the end of the document.

Stakeholders in the VPC sectors need to address key challenges facing VPC seed producers and users such as the lack of specific regulations for VPCs and standards, especially in the countries which are either still developing such standards and regulations, or entirely do not have such tools in place. The absence of crop specific guidelines and standard operating procedures result in (i) low capacity to produce quality VPC seed, (ii) poor storage and handling facilities for seed and (iii) inadequate experience, technical skills and training among the seed inspectors and certifying officials from state seed regulatory agencies, especially lack of staff specialised in certifying VPCs.

Simple, flexible and less bureaucratic systems are much more desirable for developing countries, even while countries must maintain a focus on quality control and quality assurance mechanisms within the legal provisions of seed laws, including those of novel approaches (Loch and Boyce, 2001). Quality control and quality assurance are important preconditions for ensuring the availability of planting materials and for piloting novel approaches such as decentralised seed production and quality control approaches. It is thus important for countries to mainstream and scale up sustainable quality assurance systems that work by establishing context-appropriate seed regulatory frameworks.

While individual farmers, farm-based associations, farmer cooperatives and private companies have invested and continue to invest in production of VPC seeds, public investments in this sector are needed to realise wider system change and impact. Because VPC seeds are bulky, perishable and have high disease risks, many seed companies are not interested in these crops. Therefore, is important to secure political buy-in for decentralised VPC production and devolved VPC seed inspection so that states are encouraged to invest in supporting regulatory agencies and decentralised offices to deliver their services efficiently and effectively. In turn, this will allow farmers to secure the extension services they require.

To ensure scalability and sustainability of novel approaches like the decentralisation of seed production and quality assurance, piloted initiatives must be sustained, including (i) for capacity development; (ii) providing adequate resources (competent personnel, funding and the necessary technologies like electronic platforms); and (iii) more importantly, the presence of an entrenched policy, legal and institutional framework that is implemented on the ground.

As part of the remedy for these challenges, the paper recommends that engaged stakeholders in the VPCs sector provide targeted training of seed inspectors. In many countries, seed standards for VPCs and provisions in the law were designed based on the experiences of grain (maize) seeds, which have significant differences with VPCs. Therefore, seed inspectors need training for inspection of VPCs (i.e. varietal identification, crop specific pests and diseases). This can be complemented by capacity development efforts at different levels; for example, (i) training extension officers to undertake inspections and how to use relevant equipment (including any ICT devices); (ii) training seed producer associations on technical and governance/administrative aspects for ensuring equity, accountability and monitoring; and (iii) training seed producers to inspect their own seed and fields.

Countries need to establish and scale up seed producers' associations. In countries where seed producer associations are in place, they have shown to be cost-effective by mobilising fellow seed producers who need seed inspections to pay inspectors as a group instead of as individuals. This has in turn also driven the demand for inspection from the relevant authorities, because inspection activities such as these generate income for government agencies. With associations in place, it is possible to help seed producers and farmers to identify markets for both seed and produce, to create a virtuous cycle whereby producers buy improved seed because they have a market for their improved produce.

Finally, stakeholders need to implement or scale up e-certification platforms like SeedTracker™ to reduce the burden and costs associated with manual and physical activities related to seed inspection and certification. Where ICT systems such as SeedTracker™ have not been implemented, roll these out in all countries, ensuring both that they are suitable for each country's specific needs, and that they align with regional and international seed policy. In countries like Nigeria and Tanzania where SeedTracker™ is in place, it is imperative that most of these tools are improved to address the current limitations. Meanwhile, achievements – including the use of successful ICT tools – need to be promoted through regular communication and dialogue at all levels, including between farmers, seed producers and breeders (about the preferred traits for improved varieties and any challenges farmers are facing), and between stakeholders (to ensure alignment on the goals of seed quality assurance, how to ensure quality, and how to address problems).

1 INTRODUCTION

Although VPCs are among the world's most important staple crops, in developing countries they have been neglected by commercial producers and even by government research institutes. In many African countries, including those included in this study, seed system regulations are based on assumptions appropriate to cereal crops, but inappropriate to the biological characteristics of VPC seed (Bentley *et al.*, 2018; Gatto *et al.*, 2021). In many cases, even when specific regulations have been established for VPCs, countries have weak enforcement systems and/or improved or certified seed is not available, so farmers continue to acquire planting material from people they know or to purchase from traders with a good reputation that they trust and with whom they have a long-standing relationship (Gatto *et al.*, 2021). Therefore, strict enforcement is neither advisable nor practical in the short term. Strict centralised control measures for crops such as VPCs tends to limit the market size (Spielman *et al.*, 2021); seed producers have no incentive to invest in these seeds, especially as they do not travel well, being more perishable and too bulky to transport across long distances (Bentley *et al.*, 2018). Therefore, seed production for these crops mainly happens at a local level, where the capacity and reach of seed producers are limited (Spielman *et al.*, 2021). This points to the need for formal integration to be based on the decentralisation of seed production and support for small-scale seed enterprises (Sperling, Boettiger and Barker, 2013).

However, local seed multiplication can be problematic: while it is a benefit to the farmer that VPC seed remains unchanged across the production system, if the plants are not flushed every few years, diseases can infect the entire stock (Bentley *et al.*, 2018). Therefore, seed development that incorporates rapid multiplication technologies (RMTs) can help to address the low multiplication rates that are typical of VPCs, and improved varieties can be introduced to farmers and their collectives so that the VPC seed system is more sustainable, based on "grassroots capacity development, market surveillance, and systems that integrate internal (producer-level) quality assurance with external (regulatory) quality assurance" (Spielman, 2020, p. iii).

Therefore, this research set out to explore to what extent seven African countries (Ethiopia, Kenya, Malawi, Nigeria, Tanzania, Uganda and Zambia) are decentralising and integrating VPC seed systems, in terms of regulations governing the sector, methods of seed production, and methods of seed inspection and certification. It consolidates existing data and presents new data on decentralised seed quality assurance (SQA) approaches for VPCs in these seven selected countries. It aims to make relevant information readily available for policy dialogue on appropriate and inclusive SQA approaches by providing an assessment of (i) the extent to which SQA has been decentralised, i.e., the extent to which third-party accredited inspectors have been deployed; (ii) countries' use of e-certification platforms; (iii) the involvement of seed producer groups and cooperatives in SQA; and (iv) any novel approaches to disease diagnostics or other relevant aspects of SQA.

Seed quality control and quality assurance are key components of seed production and marketing so that farmers can access new varieties and high-quality seed. Seed quality can be measured based on tolerance levels set by farmers and seed producers themselves and implemented using internal quality control measures, and/or the standards can be established through a formal seed quality assurance system with external seed inspections (McEwan et al. 2022 forthcoming). In theory, many African countries have fully-fledged seed certification systems. However, in practice, these systems face many challenges, and often do not function well. Simplified, decentralised and cost-effective mechanisms for SQA exist, such as the Quality Declared Seed (QDS) approaches in all the countries in this study; and ICT-based technologies such as SeedTracker™ have been deployed in some countries. Although such mechanisms have been developed and piloted, practical experiences of implementing them at scale and making them manageable and affordable are scarce, especially in relation to VPCs.

Therefore, in low-income countries, instead of focussing all legislation and regulation on the development of the formal sector and market-related seed system development, a more non-linear approach of gradually integrating the formal and informal systems may be more viable (Sperling, Boettiger and Barker, 2013). Integration involves coordinated actions between the sectors, the interdependence of the formal and informal systems, and acknowledging links between the two. Seed systems in African countries have already been integrating; for example, farmers use their own seed and seed from the commercial sector, and in some countries, farmers have also been guiding seed development with respect to the varieties they would prefer and the attributes such

varieties have. However, these steps toward integration are typically ad hoc, occur on a small scale, and have typically focussed on a few key crops (Sperling, Boettiger and Barker, 2013).

Under the auspices of Integrated Seed Sector Development (ISSD) Africa, the International Institute of Tropical Agriculture (IITA) and the International Potato Center (CIP) are the key partners for the topic "Enhancing seed quality assurance". The action learning questions are twofold: (i) How can the efficiency of decentralised SQA mechanisms be enhanced? and (ii) In developing seed policies and regulations, how can greater flexibility and options for decentralised SQA mechanisms for different types of seed producers be promoted?

Based on an online survey completed by officials from regulatory agencies from eight countries, and follow-up interviews with seed certification officials and researchers in the seed sector, the paper concludes that it is possible to make decentralised VPC seed systems a reality in the right circumstances. In some cases, countries have already made strides in doing so. However, several gaps exist in different countries, all of which need to be addressed. They include problems such as the following: (i) legislation and regulations not specifically considering the quality assurance requirements of VPCs; (ii) shortages of trained staff throughout the system and especially in far-flung areas; (iii) unavailable or inadequate training materials and handbooks; and (iv) inadequate resources at local level, including support for inspection equipment and resources (e.g., vehicles), farmers' cooperatives/associations, and monitoring and administration. Each of these and other issues are discussed throughout the report and in the recommendations at the end of the document.

2 METHODOLOGY AND MATERIALS

The paper used different, appropriately sequenced methods to ensure that different methods complemented each other to offset the disadvantages of each method. These include a comprehensive literature review, an online survey, and virtual interviews with key informants.

We, therefore, undertook a comprehensive literature review on SQA policies and legislation in the seven case study countries. This includes reviewing the findings of a Nigerian survey of National Agricultural Seed Council (NASC) seed inspectors; seed producers' and buyers' reports; and other ISSD project-related materials, academic articles, grey literature, presentations, and unpublished documents.

We gathered primary information from an online survey, with 18 respondents (17 men; 1 (Malawi) woman) from the seven countries, 15 of whom were involved in seed certification. The institutional role of respondents included 16 regulatory bodies, one policymaking or government authority, and one representative of a national research institute. Ten of these respondents at a regulatory body were at headquarters, while six were in a subregional body. In each country, we were able to get at least a response from senior management officials, mostly at the director level of the seed regulatory bodies and their senior staff with many years of seed inspection experience.

In addition, we conducted follow-up interviews with 12 key experts and government officials in the seed sector in Ethiopia, Kenya, Malawi, Zambia, Tanzania and Uganda. We also conducted expert interviews, especially with IITA and CIP experts based in Tanzania, Uganda, and Ethiopia, and one CIP expert with overall knowledge of the project countries in Africa.

Finally, all the qualitative information we gathered was analysed (using common themes); and the quantitative data from the online survey were analysed (using Excel sheets) and interpreted and used (based on the key themes set out in the terms of reference for this study).

3 LITERATURE REVIEW

From the 1980s onwards, through structural adjustment programmes, efforts were made to create a linear model for seed systems by which the informal seed system would be rapidly transformed into a formal seed system with privatised companies producing certified seed (Louwaars, de Boef and Edeme, 2013). As described by Louwaars *et al.* (2013, p. 187), a linear model

> *directs the seed sector along a fixed pathway, from informal systems to economically viable commercial seed systems, and calls for governments to take the necessary policy measures, i.e., investment and regulation, to guide the transfer of the seed sector to the next development stage.*

The linear model typically involved four stages, as shown in *Figure 1*. The model assumed that, if guided by a suitable regulatory environment, a commercial seed sector would be able to meet farmers' seed demands. However, in Central, Eastern, Southern and Western Africa this approach was only successful with respect to major cereals such as maize, rice and sorghum. Therefore, in many countries, a non-linear model is now being pursued for many crops including VPCs. The exact model in each country takes into account in-country factors and structures, including the complexity and diversity of the informal/traditional seed system; this non-linear system encompasses elements of the linear model and additional elements that considers other types of seed production and demands, as outlined below.

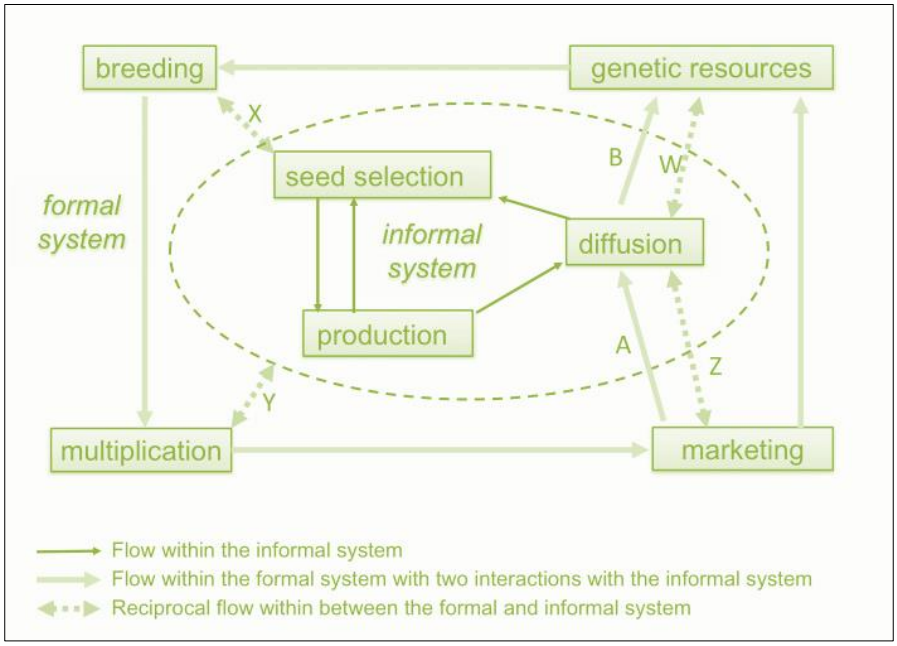
- Strengthening regulator functions in controlling the quality of seed and registering approved varieties;
- Providing enabling policies for domestic and multinational, commercial seed companies to produce and trade seed;
- Strengthening national and local commercialisation in the seed sector;
- Supporting farmers to produce better quality seed; and
- Supplying seed for emergency supplies (Louwaars and de Boef, 2012).

Figure 1: Seed sector development following a linear model in four stages

Adapted from Douglas (1980), cited in Louwaars et al. (2013, p. 189).

The elements of a non-linear model typically involve varied interactions between the informal and formal knowledge and genetic systems, with the aim of enhancing the efficiency and effectiveness of the overall system. The flow of knowledge is depicted in *Figure 2*.

Figure 2: Interactions between formal and informal knowledge and genetic resource



Source : Louwaars et al. (2013, p. 192).

Within this non-linear model, by ensuring interactions between formal and informal sectors, seed system development is meant to be flexible and dynamic, while promoting autonomy and a community focus. The model includes the recognition that in some cases seed produced by trained farmers in seed cooperatives may be of better quality than seeds of early generations produced by public agencies or research institutions (Louwaars, de Boef and Edeme, 2013). Thus, to reduce the burden of formal certification on community-based seed systems, a QDS approach is introduced, on the assumption that individual farmers and community seed producers can move towards commercialising their seed production.

Seed commercialisation requires that seed entrepreneurs are encouraged to make a successful business out of seed production by producing good quality seed (using technical skills) and marketing it to clients who can be assured of the quality (Gildemacher *et al.*, 2013). However, quality assurance need not only be dependent on well-functioning formal seed certification systems – especially, as is the case in many African countries, where certification systems are poor (Gildemacher *et al.*, 2017). Instead, seed producers can be trained on "clear, pragmatic crop-specific quality control protocols for the management of their seed crop" (p. 2) so that seed producers can monitor the quality of their seed. Such seed producers will be able to sell their non-certified seed based on having a good reputation among farmers who are buying seed.

This literature review sought to identify the extent to which the governments in the seven case study countries have developed policy and legislation for SQA in the VPC sector, based on QDS or other similar approaches. The review focused on (i) the extent to which SQA systems have been decentralised (the extent to which third-party accredited inspectors have been deployed); (ii) countries' use of e-certification platforms; (iii) the involvement of seed producer groups and cooperatives in SQA; and (iv) any novel approaches to seed quality assurance, including use of diagnostic tools for seed health testing, or other relevant aspects of SQA.

3.1 Key concepts

3.1.1 Seed quality: Quality control and quality assurance

Quality control in the seed system involves seed producers undertaking internal processes to ensure that farmers can access seeds with the required characteristics (Beavis and Harty, 1997; Grabe,

2021) and which conform to a minimum set of quality standards (Bishaw, Niane and Gan, 2007). Seed quality is related to genetic, physical, physiological purity and health or phytosanitary status, and it also influences the performance of a variety. During seed production, quality control is intended to prevent the spread of diseases, identify the causes of diseases, and remedy the problems (Grabe, 2021). Seed producers should have clear internal protocols for seed selection and production (Gildemacher *et al.*, 2016), which can include using rigorous scientific methods such as seed testing and inspection in laboratories (Abebe, 2020; Grabe, 2021) and creating test plots to monitor seed quality standards (Bishaw, Niane and Gan, 2007). Steps for maintaining quality include testing, risk identification, preventative measures, monitoring, corrective measures, procedures to verify the results, and tracking and record-keeping of seed tests and seed distribution (ASTA, 2016).

While seed producers undertake their own quality control, *quality assurance* is assessed externally from the seed production company. In informal systems, farmers sometimes rely on a relationship of trust with the seed producer to assured that they have accessed quality seed. However, quality assurance is typically undertaken by external agencies; for example, governments deploy "an autonomous and accredited body … [to] inspect every stage of production, including preparation of the seed field, the pre- and post-harvest period, processing, storage and transportation" (Abebe, 2020, p. 6). Whereas quality control is undertaken during seed production, quality assurance measures the quality of the seeds after they are produced to check that they meet technical and regulatory standards (Bishaw, Niane and Gan, 2007). At the most basic level, quality assurance starts with the truthful labelling of seed according to its purity and germination; at later stages, the system can cautiously move to certification and, as and when appropriate, seed health (Loch and Boyce, 2001). This means that a "highly sophisticated QA system is simply not warranted during the early stages" (p. 5). Quality assurance should be aligned with a country's level of development, taking national circumstances into consideration.

The ability to assure quality is dependent on the range and quantity of improved varieties available, the level of mechanisation in the country, available storage facilities, and the cost of seed production (Bishaw, Niane and Gan, 2007). As such, in many developing countries, it may not be appropriate to introduce similar seed laws to those of developed countries, for example, by insisting on a rigid bureaucratic system rather than simple, flexible arrangements (Loch and Boyce, 2001). A rigid system could stifle the development and innovation through which local varieties are developed and also hinder the sale of seed due to the costs involved.

3.1.2 Decentralisation

Decentralisation in the SQA context typically involves devolving and delegating power, duties and functions to quasi-public corporations, local governments, and NGOs (Rondinelli, Nellis and Cheema, 1983), and in some instances the private sector. However, to work effectively, decentralisation must go alongside skills development and transfer of financial resources to those to whom power, duties and functions have been devolved and delegated. The reasons for decentralising central government roles vary but may include (i) improving resource distribution to local areas, (ii) improving community participation in decision-making, (iii) extending the ability to deliver public services to far-flung areas, (iv) increasing the ability to identify and implement locally relevant projects, and (v) boosting employment.

With respect to the seed system, decentralised seed production aims to bridge the gap between formal and informal seed systems in developing countries to ensure the delivery of certified or quality assured seed from research laboratories to fields (Mausch *et al.*, 2021). Apart from optimised seed production and distribution, decentralisation can also optimise quality assurance by bringing services closer to seed producers (Spielman and McEwan, 2020). Arguably, a decentralised system offers an opportunity to better produce, market and deliver the appropriate VPC seed for specific agro-ecologies and locally preferred varieties, while also reducing the costs of seed due to lower transport costs (Alemu, Yirga and Bekele, 2018).

Opportunities for decentralisation exist across the seed system "from breeding, to source seed maintenance and multiplication, to basic seed and certified seed production and distribution to price setting" (Alemu, Yirga and Bekele, 2018, p. 75). As discussed above, decentralisation can include the private sector and quasi-public corporations, local governments, and NGOs, and each of these can play a role in improving the seed system. For example, it might be possible to (i) involve the

private sector in seed certification; (ii) train farmers and local extension officers in seed inspection; (iii) have seed testing facilities at regional level; (iv) designate research institutions in each region to research improved varieties for their region; and/or train farmers or farmers' groups who already produce seed for the local seed system to use new seed technologies to boost local seed production. However, it is also important to pay attention to the politics of the seed system, as decentralisation gives more power and finance to local and regional structures. Thus, decentralisation has many political impacts, some of which the central government might seek to avoid.

4 FINDINGS

The findings presented in this paper are those gathered from the online survey and key informant virtual interviews carried out as a follow-up to the online surveys. First, we present the overall findings on the following: the crops for which certification of seed is mandatory; seed classes; and the years in which countries formulated seed policies and standards for specific VPCs.

Online survey respondents indicated that VPC certification included banana (5 respondents), cassava (8 respondents), potato (9 respondents), sweetpotato (7 respondents), and yams (4 respondents) (see *Table 1*). Other crops where seed certification was undertaken were Beni seed/sesame, cowpea, cotton, maize, millet, rice, sorghum, and soybean. As the table below shows, maize and sorghum are the crops that are most certified by seed regulatory agencies.

Table 1: Crops for which seed is certified

CROP	TOTAL	ETHIOPIA	UGANDA	KENYA	NIGERIA	TANZANIA	MALAWI	ZAMBIA
Maize	11	2	1	2	2	2	1	1
Sorghum	11	2	1	2	2	2	1	1
Soybean	10	1	1	2	2	2	1	1
Rice	10	1	1	2	2	2	1	1
Millet	9	1	1	1	2	2	1	1
Potato	10	2	1	2	1	2	1	1
Cotton	9	0	1	2	2	2	1	1
Cowpea	8	0	1	1	2	2	1	1
Cassava	8	0	1	1	2	2	1	1
Sweetpotato	7	0	1	1	1	2	1	1
Banana	6	1	1	0	1	2	1	0
Yam	4	0	1	0	2	0	1	0
Beni Seed	4	0	1	0	2	1	0	0
Other	5	tef, wheat, haricot beans, coffee, spices	all seeds	beans	0	0	groundnut	beans, groundnut, tobacco, barley, wheat

Note: numbers per country represent the officials who responded to an online survey, for example, Kenya there were 2 respondents who completed the survey. The totals are for only those officials who responded for each crop that they inspect and certify. Some officials skipped some questions including this one.

Regarding the VPC seed types certified, nine (9) said they certified tubers, eight (8) said they certified stem/vine cuttings, seven (7) said they certified vegetative propagules, and four (4) said they certified suckers (see *Table 2*).

Table 2: Seed types certified

CROP	NUMBER OF RESPONDENTS
Open-pollinated seed	10
Tubers	9
Stem/vine cuttings	8
Vegetative propagules	7
Rooted plants	6
Suckers	4
Genetically modified (transgenic)	4
In vitro plants	3
Bulbs	3

Regarding digital record keeping and digital certification tools, only ten (10) respondents answered, of which half (5) said that information was manually recorded and filed and only entered onto a computer later, and half (5) also said their institution used digital data collection and electronic certification tools. Tanzania and Nigeria are the only two countries which have piloted a much more specific digital seed tracking tool – the Seed Tracker.

Of the countries in this study, the first countries to craft their seed laws were Uganda and Zambia with their laws in place in 1962 and 1965 respectively. Kenya, Malawi, Nigeria and Tanzania enacted their Seed Act in 1971 and 1975. Ethiopia is the only country which according to online responses had instituted seed law in 2015. Most of these countries have since then reviewed and amended their Seed Laws.

Below we unpack the extent to which seed production is decentralised, inspection services are devolved and we then provide an overview of each of the key novel approaches and or issues.

4.1 Decentralisation

Due to the bulky and perishable characteristics of the seed of roots, tubers and bananas, decentralised seed production models can reduce transport costs and ensure closer access by farmers (Singh *et al.*, 2019). Community or locally-based seed production by trained farmers is one option; others may include registered seed companies using out-growers to produce seed and local distribution networks through agro-dealers. As shown in the literature review, farmers favour specific varietal characteristics, the chief of which is achieving high yields, but also characteristics such as resistance to disease and resilience to local climate. For the seed of roots, tubers and bananas, due to the vegetatively propagated nature of the crops, there is a higher risk of accumulation of pests and diseases, so confirming the phytosanitary status of the seed is critically important. Hence the importance of quality control measures during seed production and quality assurance through seed certification is important. The use of decentralised seed production models, therefore, raises the need for decentralised seed quality assurance.

A decentralised model is especially appropriate with respect to VPCs because vegetative seed (stems, tubers, vines, etc) cannot be transported long distances, so needs to be produced close to where farmers will plant it (Bentley *et al.*, 2018). The seven African countries in this study are at different stages of developing seed policies which incorporate the specific needs for VPCs, including devolved seed certification in support of decentralised VPC seed multiplication. The main form of VPC seed production is at local level; 15 of the 18 respondents – from Tanzania, Malawi, Ethiopia, Nigeria, and Kenya – stated that seed certification for VPCs is decentralised in their countries, and three respondents – from Uganda, and Zambia – stated that certification is still centralised and conducted by the head office.

As we will show below in the discussion of each country, different models are appropriate to different local circumstances and VPC seed multiplication differs across crop types, so seed policy,

certification, production and inspection approaches need to be adapted to the different crop types. This aspect of the study is further elaborated in the discussion.

Below, we describe how processes of both decentralisation of seed production and devolution of seed inspection are being undertaken in each of the seven countries. For each country, we start with a brief overview of the regulatory environment for the seed system and the procedures that have been applied in seed production, before shifting focus to decentralised VPC seed production and devolved seed inspection.

4.1.1 Ethiopia

The Ethiopian government's strategy for transforming the seed system includes a community-based intermediate system to distribute non-certified seed. This seed is not fully regulated by the regional Bureaus of Agriculture and Natural Resource Development, but it is of higher quality than seed produced in the informal sector (Agricultural Transformation Agency, 2016). NGOs and breeding centres provide financial and technical support to farmers to produce seed (Hirpa *et al.*, 2010) and farmer-based seed multiplication schemes (FBSMSs) are expected to start meeting seed supply needs (Ayana, 2019), although operations are still small-scale (Ministry of Agriculture, 2020). The intermediate system is based on the insight that Ethiopian farmers are increasingly adopting certified seed for some crops (e.g. 25% of maize seed) due to organised seed production by the Ethiopian Seed Enterprise (ESE). However, ESE does not provide VPC seed due to its limited capacity (Hirpa *et al.*, 2010; Agricultural Transformation Agency, 2016).

Schulz *et al.* (2013) argue that it is unrealistic to imagine that the informal VPC seed system in Ethiopia could be rapidly changed to a formal certified seed system since the costs to implement such a system would be prohibitively high because of the logistical challenges associated with Ethiopia being a large country with poor road infrastructure. Hence, the decentralisation model is suggested.

Decentralised VPC seed production

Ethiopia is fostering farmer group organisations for seed production. Cooperative seed production is being promoted because the public sector has not managed to develop a sustainable potato seed sector that can efficiently provide farmers with quality seed of improved varieties (Tadesse *et al.*, 2020). Further, potato seed production has been shown to empower women's farmer groups. This intermediary system is being applied to seed potato production, whereby NGOs and breeding centres provide financial and technical support to farmers to produce seed tubers (Hirpa *et al.*, 2010). Hundreds of seed potato cooperatives have been set up since 2007, and by 2017 "more than 20% of the national seed potato demand was supplied by seed potato cooperatives in Ethiopia" (Tafesse *et al.*, 2020, p. 2). In some parts of Ethiopia, farmers' research groups and farmers' field schools have been set up, supported by the Ethiopian Institute of Agricultural Research (EIAR), and these farmers have become specialised seed potato growers (Hirpa *et al.*, 2010). While the seed tubers they produce are better quality seed tubers than those of other informal seed producers, they "may still not be of standard quality" (p. 540).

For such projects to be successful, farmers have to meet various criteria, such as owning or having access to a minimum plot size. For example, in a study of two cooperatives in Chencha, Ethiopia, that are supported by an Irish NGO, selected farmers had to show diligence, own a minimum of 1.5ha of land, contribute membership fees to the cooperative, and sell the potato seed via the cooperative for cash (Tadesse *et al.*, 2020). For such projects to be successful, cooperatives require much support, such as being assisted to organise pooled labour for farming activities and being provided with "improved seed, construction materials for building improved seed storages and training in agronomic and storage practices by extension professionals" (p. 151). However, in this case, the selection criteria for the farmers favoured wealthier farmers with better access to land and finance, and they did not necessarily see the benefits of working as a cooperative. Further, the supporting NGO focussed more on developing seed production capacity than on building good governance within the cooperative, such that "the tensions between prescriptive rules, collective action and individual interests … made it very hard to maintain quality seed standards and friendship at the same time" (Tadesse *et al.*, 2020, p. 139).

In addition, if seed quality is not monitored on an ongoing basis, within cooperatives, farmers sharing tools can inadvertently spread disease (Tafesse *et al.*, 2020). Therefore, "monitoring

disease occurrence and management by seed potato cooperatives … [is essential] in ensuring quality seed production" (p. 2).

Theoretically, for sweetpotato seed production, Ethiopia operates at the regional level, with regional Agricultural Inputs Quality Control and Quarantine Authorities (AIQCQA) controlling the quality of (i) pre-basic and basic seed that are produced at research institutions and sold as vines to seed multipliers; and (ii) vines produced by multipliers before they sell them (Gurmu, 2019). However, "the enforcement agencies have limited capabilities in terms of laboratory facilities, vehicles, and adequately-trained personnel" (Mabaya *et al.*, 2017, p. 4). Furthermore, the facilities are distant from some seed producing areas, and the long travelling distances complicate inspection logistics. These factors lead to fewer inspections taking place than are needed.

Devolution of VPC seed inspection

Only 32 public sector seed inspectors are registered in Ethiopia, and although private companies have their own seed inspectors, they are not licensed by government (Mabaya *et al.*, 2017). As such, the number of inspectors is inadequate to meet the country's needs.

In a case in Chencha, no handbooks had been provided for potato seed inspection to address quality assurance and the relevant committees were understaffed and lacked the necessary skills to assess plots when potatoes were flowering and when they had been stored in seed lots (Tadesse *et al.*, 2020). Furthermore, local governments are meant to provide guidance on seed production and seed quality maintenance, such as "threshold values for the number of diseased or wilting plants in the field or affected tubers in storage … rules for the disposal of rogued plants … [and] in relation to financial compensation for the affected producers" (Tadesse *et al.*, 2020, p. 152). Where such guidance has not been established, outbreaks of disease have occurred. This has happened in Chencha; an outbreak of bacterial wilt "resulted in a rather unexpected high pressure on the farmer cooperative groups, adding to the more common pressure of virus diseases and late blight (*Phytophthora infestans*)" (p. 151).

Another study on decentralised VPC seed inspection in Ethiopia, in this case focussed on sweetpotato, found that a pilot project on informal seed inspection had resulted in none of the pilot sites meeting tolerance levels due to the presence of sweetpotato viruses, and a lack of record-keeping with regards to "source of planting material, rotation practice and date of planting; scattered fields and fields at different stages"(McEwan, 2014, p. 6). Therefore, the planting material was not acceptable for distribution.

4.1.2 Uganda

Two key documents provide guidelines for the Ugandan seed sector: its *National Seed Policy* (Ministry of Agriculture, Animal Industry and Fisheries, 2018a) and its *National Seed Strategy* (Ministry of Agriculture, Animal Industry and Fisheries, 2018b). The vision for the country is that subsistence farming should be transformed into commercial agriculture that uses high-quality seed and other agricultural inputs; therefore the seed strategy aims to create a well-regulated competitive, profitable and sustainable seed sector where farmers can access affordable safe, high-quality seed and planting materials. Driven by the Ministry of Agriculture, Animal Industry and Fisheries' (MAAIF) policies of privatisation, liberalisation and divestiture, the formal seed system is now private-sector led and meant to ensure that farmers have a reliable seed supply system. While many private sector and research institutes exist to develop pre-basic and basic seed, the production programmes focus on maize, bean, millet, and sorghum. Therefore, the Ugandan government has accepted and moved towards a more decentralised system in the case of VPCs due to lack of private sector engagement, which is discussed below.

Decentralised VPC seed production

Because farmer-led seed companies and cooperatives can supply locally at cheaper prices than nationally operating seed companies that need to transport seed over long distances, a semi-formal QDS seed system has evolved in Uganda (Spielman, 2020). In this system, seed is produced by local farmer-led enterprises and inspected by district agricultural officers, creating a decentralised seed system. The system has led to professionalisation among local seed producers, "and the number of farmer groups producing and marketing the QDS class is increasing" (Mastenbroek, Otim

and Ntare, 2021, p. 12). The QDS classification focuses on seed other than maize, especially open/self-pollinating or vegetatively propagated crops (Spielman, 2020; Kuhlmann and Dey, 2021).

Much progress has been made in Uganda's VPC seed sector since 2011, with the national seed policy having been updated to include VPC certification and inspection, and various partners – NGOs, the public and private sector and farmers – having been actively involved in establishing "active chain structures for production and dissemination of early generation to quality-declared seed" (Namanda *et al.*, 2021, p. i). The focus of these interventions is on achieving higher crop productivity by producing and disseminating clean planting materials. Nevertheless, while some groups, associations or cooperative societies have begun operating in the sector, these groups are generally only successful in managing without support from the development partners if they are generating revenue through commercialisation, such as in the case of potato. Accordingly, "removing NGO logistical support and coordination would lead to the collapse of most seed producer associations" (p. 26). As one interviewee explained, in Uganda, one novel approach to VPCs approach, implemented by CIP, was to involve farmers and their associations in the learning process and give farmers the opportunity to practice, observe and report to project implementing partners (Interview, 24 June 2022).

Typical VPC crops in Uganda include potato, sweetpotato, banana and cassava. Seed companies in the country have little incentive to produce certified seeds for crops such as cassava and potatoes because profit margins are low and local areas have preferences for specific varieties (Mastenbroek, Otim and Ntare, 2021). Each of these crops is discussed below.

In Uganda, sweetpotato is one of the most important root and tuber crops, but has not yet reached its full potential as despite the crop covering a 4 million ha area, yields are low (Wokorach, Edema and Echodu, 2018; Andersen *et al.*, 2019). Farmers typically use their own saved vines from the previous year or acquire them from family or neighbours; however, sweetpotato vines are also sold across county borders(Namanda, Gibson and Sindi, 2011; Wokorach, Edema and Echodu, 2018; Andersen *et al.*, 2019). Vines are typically selected based on a healthy appearance, and in both formal and informal seed systems, farmers usually choose and cut the vines (Namanda, Gibson and Sindi, 2011). However, the farmers, who are typically women, mostly do not have information about how to limit the spread of disease, do not know how to identify diseases, and do not know the origins of those diseases (Andersen *et al.*, 2019). For those purchasing vines, a shortage of planting material means that farmers are accessing it late in the season, which limits the amount farmers are able to plant; many are interested in purchasing more seed should it become available at a good price (Namanda, Gibson and Sindi, 2011). While various associations and cooperatives exist in the sweetpotato seed sector, these groups tend to be for more than one crop because sweetpotato production has not been commercialised and therefore raising revenue is difficult. However, this situation is creating more pressure on sweetpotato cultivation to become more commercialised, with an impact on the amount of land under sweetpotato cultivation, but with not much increase in yields as quality planting material is difficult to access.

Potato is also an important staple crop in Uganda and potato production is increasing due to increasing demand and consumption, driven by urbanisation and population growth (CIP, 2022). However, the yields for potato are low due to poor quality seed and many farmers' failure to apply good agricultural practices. In recent years, efforts have been made to "[introduce] robust potato varieties, rapid multiplication technologies for early generation seed production, promotion of seed potato production by private seed businesses to increase supply, development of seed potato inspection and certification guidelines, deployment of diagnostic tools for several diseases, and capacity building of value chain actors in good potato management practices and collective action" (p. 2). Furthermore, Uganda has developed a seed certification protocol which MAAIF will process and ratify; a taskforce including stakeholders will then evaluate the effectiveness of the protocol (CIP, 2021).

Cassava is another important food crop grown in many parts of Uganda (Nakabonge, Samukoya and Baguma, 2018). A wide variety of cassava may be grown, mainly for home consumption and not for sale. Farmers, especially commercial farmers, are increasingly buying improved varieties that are less susceptible to pests and disease, require less land for cultivation, and have a shorter maturity period; but lower-yielding local varieties are still highly favoured (Nakabonge, Samukoya and Baguma, 2018).

While bananas are grown for household consumption in Uganda, it is also "the main income source of many households and has had a pivotal role in raising income from farming" (Kilwinger, Rietveld and Almekinders, 2019, p. 1). Many banana plantations have existed for so long that the current farmers have inherited them and cannot remember when they were planted. "Like many other VPCs, banana 'seed' from farmers' own farms is often used (59% of 'seeds' used), as well as acquiring (about 70% gifted and 30% bought) from friends, relatives and neighbours, with only about 5% of 'seed' acquired from the formal system. New planting material comes from suckers – offshoots of the main banana stem of a mother plant, which means that 'seed' is not produced separately for crop cultivation. Women tend to "manage higher cultivar diversity" but at this stage it is unclear why women seek more suckers on banana plants and men fewer suckers" (de Haan, 2021, p. 6). Further, bananas have unique, haphazard replacement dynamics, in that plantations are maintained with new planting material being planted in gaps where old plants have died or when farmers uproot low performing plants (Kilwinger *et al.*, 2019). When introducing cultivars from the formal systems (the National Agricultural Research Organization, the National Agriculture Advisory Services, and a private-sector company, Agro Genetic Technologies Ltd (AGT)) they plant these cultivars in between existing plants on their plantations so as to conserve cultivar diversity; so a "flexible blend of formal-informal" seed production approaches is needed to meet the multiple needs of farmers (Kilwinger *et al.*, 2019, p. 456). Apart from preserving diversity, removing existing plantations would be labour-intensive and farmers may also be reluctant to buy from the formal system when they cannot examine the mother plant for diseases and check which cultivar they are purchasing. However, farmers also recognise that there is limited planting material on their own farms and in their social networks, so they sometimes use substandard planting material, and would be open to gradually introducing new varieties from which new planting material (suckers) can be obtained.

Devolution of VPC seed inspection

Much progress has been made in Uganda's VPC seed sector since 2011, with the national seed policy having been updated to include certification for different VPCs and inspection, and various partners – NGOs, the public and private sector and farmers – having been actively involved in establishing "active chain structures for production and dissemination of early generation to quality-declared seed"(Namanda *et al.*, 2021, p. i). The focus of these interventions is on achieving higher crop productivity by producing and disseminating clean planting materials. QDS is still subject to inspection, but the number and frequency of inspections are reduced and farmers' groups are trained to establish "internal quality control mechanisms that are then verified by the inspector" (Kuhlmann and Dey, 2021, p. 20). Inspectors give significantly more attention to maize seeds than any other seed types, so "a large portion of seed sold to farmers is not inspected" (Mabaya, Waithaka, *et al.*, 2021, p. 9).

However, since 2018, the National Seed Certification Services (NSCS) is being transformed into the semi-autonomous Uganda Plant Health and Inspectorate Agency (UPHIA), which is "responsible for all phytosanitary services, seed regulatory services, and agricultural and plant-related chemical regulatory services … [and] is expected to improve efficiency of service delivery" (Mabaya, Waithaka, *et al.*, 2021, p. 19). In 2019, NSCS only had 19 seed inspectors (15 men and five women), of whom five were deployed at airports and were unavailable for seed inspection in the field or laboratories. Seed inspection is further limited by inadequate financial resources, equipment and infrastructure to train and deploy inspectors. Extension officers are now being trained to conduct field inspections in major seed producing districts but an initiative to authorise private-sector inspections services collapsed in 2018.

As one interviewee pointed out (Interview, 24 June 2022), in Uganda the inspection of seed of VPCs is decentralised into different regions, but there are regions without inspectors. Therefore, it is safe to say that inspection is partially decentralised so that farmers can reach them when they need them. As a result, currently, one inspector may have ten districts to run or supervise. To address this situation, it is necessary for inspectors to build the capacity for a few farmers so they can have internal inspection capacity.

Nevertheless, like some of the other countries in this study and as discussed later in this report, Uganda has introduced an electronic seed inspectorate management system to ensure traceability and seed tracking with digitised tamper-proof seed labels (Mabaya, Waithaka, *et al.*, 2021). In addition to the electronic labels, the Uganda Seed Trade Association (USTA) is also spearheading the introduction of a self-regulation internal QA system using random audits and independent

laboratories. It also proposes working with the government to revive training seed inspectors among seed company staff.

4.1.3 Kenya

In 2016, Kenya introduced far-reaching legislation designed to modernise seed systems and markets for an entire range of crops cultivated in the country, including VPCs (Brooks, 2014). The law states that seed certification is compulsory, and that the sale of uncertified seed is illegal. According to Brooks (2014), in adopting this approach, Kenyan seed policy conflates a 'technical fix' for low seed quality with a market-based seed system, thus leading to a lack of support for local innovation. Part of the reason that the policy does not look at ways to integrate the informal and formal seed sector is that the policy was influenced by powerful actors in the sector who promoted a market solution to problems such as insufficient agricultural extension workers. However, commercial seed is often expensive, and a good harvest is not guaranteed in some of Kenya's dryland environments.

Monitoring seed quality, overseeing seed imports, and certifying seed producers and their plots is centralised under the auspices of the Kenya Plant Health Inspectorate Service (KEPHIS); it views certified seed as the only viable option for Kenyan farmers going forward (Sulle and Mudege, 2021). KEPHIS has been strongly pushed by the Seed Traders Association of Kenya (STAK) to adopt the standards set by the International Seed Federation (ISF) and the African Seed Trade Association (AFSTA), and some stakeholders are concerned that this approach might not be the best way to transform the informal seed sector. KEPHIS also acknowledges that the seed certification process is slow, mainly due to a lack of seed certification facilities. As a result, the private sector pushed for a decentralised inspection and certification process, which allows businesses to undertake their own testing (Sulle and Mudege, 2021); this change is now being rolled out as discussed below. KEPHIS monitors seed production and undertakes seed certification of registered crops. Its duties include inspecting seed and machinery, supervising the delivery of seed crops, and seed processing, labelling, and monitoring at distribution points.

However, the policy fails to identify a role for farmer-based seed systems – including those for VPCs – and many of the clauses in the seed policies and regulations create barriers for seed producers who want to register their plots and production processes (Brooks, 2014; Sulle and Mudege, 2021). Given the lack of certified seed for some crops, most farmers are highly dependent on farmer-saved seed, farmer-to-farmer seed exchange, and NGOs that train farmers in "clean" (but inherently illegal) seed production and distribution (Okello *et al.*, 2019).

Decentralised VPC seed production

In the literature on VPCs in Kenya, the two main crops discussed are sweetpotato and potato. With regard to seed potato, sufficient land and resources are needed to ensure that seed production meets rotation and isolation standards and inspection costs (McEwan *et al.*, 2021). However, this limits the possibilities for equitable involvement in seed production in the country, for example, excluding those women who might only have limited land access. Further, given that it is illegal to produce uncertified seed, many small-scale seed potato producers argue that it does not facilitate quality seed production, but simply results in seed policing.

Kenya's potato seed system consists of many different actors serving different market segments and offering different products, such as certified seed vs. clean seed[1] (McEwan *et al.*, 2021). These different actors have conflicting ideas of what the best seed strategy for Kenya should be, especially in light of Kenya's 2010 Constitution which devolves power to county governments. While the Kenya Plant Health Inspectorate Service (KEPHIS) has the overall authority for ensuring only certified seed is produced and distributed, if the process were decentralised, KEPHIS and county governments could cooperate by KEPHIS including training of county government and seed producers within those counties. At present, KEPHIS is blamed for the short supply of VPC seed because of its stringent application of certification requirements, designed to control the quality of grain seeds (McEwan *et al.*, 2021).

[1] In Kenya, clean seed is "the first generation of seed potato produced from certified seed potato by trained farmers, through guidance of trained agricultural officers" (Ong'ayo et al., 2020, p. 132); however, this type of seed is not recognised by the Kenya Plant Health Inspectorate Service (KEPHIS).

Nevertheless, some farmers have adopted decentralised clean seed potato multiplication agri-enterprises (CSPMAEs) to deal with the limited availability of certified seed and the way that seed oligopolies in the private sector are driving up potato seed prices (Ong'ayo *et al.*, 2020). Notably, however, CSPMAE is not always feasible: turning it into a successful enterprise requires having extensive networking capabilities and a good grasp of the needs of those to whom the seed producer is selling (Ong'ayo, 2021). Additionally, seed producers need good storage facilities to maintain the quality of their seed and prevent post-harvest losses. Success is also influenced by socio-economic factors, the gender of the household head, literacy levels of the farmer, and the amount of land available for seed production. Another approach to developing the potato seed sector is quality declared planting material, which allows a decentralised approach to seed production based on the visual inspection of seed for signs of bacterial wilt (Parker *et al.*, n.d.). This approach proves more effective in ensuring quality seed than an approach that favours farmer-saved seed.

With regard to sweetpotatoes, several efforts have been made – spearheaded by KALRO, KEPHIS and CIP – to develop new improved varieties and quality seed selection (Mwangi *et al.*, 2020). Despite these efforts, sweetpotato farmers continue to face problems accessing quality planting material. Therefore, the farmers (and especially those with poorer households) face seed insecurity. However, even farmers with relatively large pieces of land face seed insecurity, because they need to access more planting material to cover the land area, and even those who live close to markets do not necessarily have greater access to planting material, because this is rarely available in local markets. In the face of these issues, farmers have been found to be open to the idea of purchasing clean seed to grow sweetpotatoes, and therefore, seed producers could develop and economically viable business selling clean sweetpotatoes if they could control their transaction costs and establish an efficient distribution system (Mwangi *et al.*, 2022).

Devolution of VPC seed inspection

Monitoring seed quality, overseeing seed imports, and certifying seed producers and their plots in centralised under the auspices of KEPHIS. However, room is now being made to certify inspectors from the private sector; there are now 47 seed inspectors in the country (35 public inspectors and 12 private sector inspectors), with KEPHIS having trained both public sector and private sector inspectors (Waithaka *et al.*, 2019). By 2019, 30 more inspectors had been trained but had not yet been registered (we could not find research confirming whether they were now registered, but many companies were hoping to register their staff after training with KEPHIS). Before being registered, the private-sector inspectors "have to obtain letters of commitment from their employers safeguarding their independence without undue influence or threats" (Waithaka *et al.*, 2019, p. 8). The private sector inspectors remain attached to a public inspector until they are regarded as having sufficient competency, after which they are allowed to operate independently.

As an interviewee explained on 29 June 2022, while KEPHIS is a national body within the Ministry of Agriculture mandated to do seed certification, it does train and license independent inspectors to do inspection. The condition for one to become an independent inspector is that one must be from a seed company. The trained and examined personnel are thus entrusted to do inspection and KEPHIS remains with an auditing role only. Further, KEPHIS has launched several programmes to raise farmers' awareness on how to identify fake seed, and it has rolled out a free SMS system called *Mulika Mbegu Mbovu* (Expose Bad Seed), through which farmers can report seed quality problems directly to KEPHIS. Seed packets also now contain a unique code by which the seeds can be verified on the KEPHIS system.

4.1.4 Nigeria

In Nigeria, the *National Agricultural Seeds Council Act* (2019) and *National Seed Policy* (2015) focus on developing the private seed sector, including varietal development and registration, rapid multiplication of new varieties, and improved seed quality sold to farmers (Federal Ministry of Agriculture and Rural Development, 2015). All breeder seed, including that for vegetative crops, is expected to meet the standards set by NASC and must be regularly inspected through a joint public-private monitoring system, in accordance with the Seed Act and Harmonized Seed Rules and Regulations. The policy also protects intellectual property rights (IPRs) and sets out that seed industry researchers, inventors and investors will receive royalties for varietal development.

To boost the private seed sector, the government must also provide incentives, such as granting pioneer status, providing concessionary interest rate loans, exempting import duties on imports of equipment, exempting seeds from sales tax, and liberalising letters of credit in accordance with foreign exchange regulations (Federal Ministry of Agriculture and Rural Development, 2015). However, the privatised seed sector has focused on maize, rice, sorghum and soya (Mabaya, Ajayi, *et al.*, 2021). While it is expected to start production in millet, wheat, cassava, pulses and oil, many of the seed companies do not have the needed capacity for production, marketing, and financial management, have limited infrastructure and do not have adequate industry/marketing information (National Agricultural Seeds Council and Seed Entrepreneurs Association of Nigeria, 2020). Therefore, government is expected to remain involved in producing and distributing enough high-quality seed to relevant crop farmers, withdrawing over time to create an enabling environment for the private sector, including government contracting accredited seed producers who will be guided, supported and supervised so that their businesses can grow and become self-sustaining (Federal Ministry of Agriculture and Rural Development, 2015).

Farmers are still allowed to use, exchange, share and sell their farm-saved seed without needing to be registered "provided they do not commercialize production emanating from proprietary varieties" (Federal Ministry of Agriculture and Rural Development, 2015, p. 18). Nevertheless, government intervenes in the informal seed sector to encourage farmers to switch to purchasing seed in the formal sector; incentives include extension education, training schemes related to seed, assisting informal farmers with research about participatory breeding techniques, and developing simple seed conditioning and storage facilities.

Decentralised VPC seed production

The VPCs in Nigeria that receive the most attention in the literature are yams and cassava, both of which are important food and cash crops. About 75% of the world's yam production occurs in Nigeria; it supports the food and income security of about one-third of Nigeria's population; and it is the highest source of calories in Nigerian diets, as well as the highest source of protein (Stuart *et al.*, 2021; Maroya *et al.*, 2022). Although most yam farmers buy some new seed every year, making seed demand high and making seed production commercially viable, few farmers specialise in yam seed production. However, those invested in yam seed production, given the right intervention, would benefit from the introduction of 24 varieties of improved yam seed that have been released since about 2001 (Stuart *et al.*, 2021). Because the yam seed market is well-organised and vibrant, introducing improved varieties could have a huge impact without the necessity for legislation. However, some legislation has been developed to set certification standards and QA standards (Maroya *et al.*, 2022).

Yam is traditionally propagated from tubers and about 30-40% of the ware harvest is used for seed yam (Stuart *et al.*, 2021; Maroya *et al.*, 2022). Small tubers from ware sweetpotato are used whole and larger ware tubers are cut into pieces (setts), which leads to the plants being highly susceptible to being infected with a range of viruses, nematodes and bacteria (Stuart *et al.*, 2021; Maroya *et al.*, 2022; Osei-Adu *et al.*, 2022). Further, the multiplication rate is slow, yams have a long growth cycle and are dormant for long periods (Osei-Adu *et al.*, 2022).

Therefore, some projects have attempted to involve communities in improving farmer-saved seed through positive selection (PS), whereby farmers identify healthy-looking plants in the field and harvest them for seed crops to be used in the following season (Osei-Adu *et al.*, 2022). Further, the PS seed is treated with fungicides and insecticides and the soil is treated with neem leaf powder. While the PS production proved more labour intensive than traditional methods, farmers achieved higher yields and higher profitability.

Another project used minisett production to achieve an increased multiplication rate and reduce the amount of planting material needed (Mignouna *et al.*, 2013). It broke the cycle of disease and produced more uniform crops; this system requires less labour, is more cost-effective, and is considered a "viable enterprise that offers an opportunity to increase yam productivity and profitability in the region" (p. 225).

Other projects have developed certified seed using RMTs and thereby cleaned both improved and local varieties (Maroya *et al.*, 2022). Five seed companies have also begun certified foundation and second-generation foundation seed production. NGO workers, extension officers and farmers have been trained and farmers using improved seed are seeing increased yields.

As with yams, Nigeria is the largest global producer of cassava and the crop provides both food and income for farmers (Olayide *et al.*, 2021; Madu *et al.*, 2022). While there is a well-developed regulatory environment for cassava seed, many stakeholders argue that "the existing quality assurance system is too stringent, too costly, and ultimately ineffective" (Wossen *et al.*, 2020, p. 22). In the cassava seed system, many farmers (about 60%) are using improved varieties, often from the Agriculture Development Program (ADP), but most farmers use several varieties in their own fields so that their crops have a range of traits (Bentley *et al.*, 2017; Pircher and Almekinders, 2021). Apart from the 60%, a further 15% have tried improved varieties but stopped using them because planting material was not available in sufficient quantities (Bentley *et al.*, 2017). Accordingly, "when growers get a new improved variety, the farmers plant the material, and evaluate it, and usually plant it on a larger scale. Improved varieties tend to replace local varieties" (p. 64). Because of the low availability of new varieties, some farming communities have been using the same varieties for 50 years; however, in recent years, a communication network facilitated by mobile phones has become the "backbone of cassava stems brokerage" which is resulting in new varieties being introduced (Pircher *et al.*, 2019, p. 6).

More farmers, especially youth, are now engaged in seed production, with most generating a profit, albeit the larger producers generating greater profit (Olayide *et al.*, 2021). Where projects have involved women in seed entrepreneurship, women have been empowered within their villages, for example being more involved in decision-making. These results suggest that a sustainable seed production system is viable "via the three-pronged indicators of social sustainability (women's empowerment), economic sustainability (profitability), and environmental sustainability (varietal adoption)" (p. 5).

However, the potential size of the cassava seed market may be quite small, because the quality of planting material from improved varieties can be maintained for about ten years (Wossen *et al.*, 2020). Because of this, "the costs of building a formal and well-regulated seed market around a market with this unique characteristic may be uneconomical or even impractical" (p. 24), even though some type of distribution for improved varieties is needed. Therefore, decentralisation and localisation are necessary to ensure cassava seed development.

Devolution of VPC seed inspection

In 2019/20, only 60 public seed inspectors were registered in Nigeria (53 men; 7 women); reportedly, several senior seed inspectors had retired and been replaced with less experienced new hires (Mabaya, Ajayi, *et al.*, 2021). With respect to seed production data, NASC also believed that some field officers were under-reporting production so that private seed companies could reduce the costs of inspection, resulting in some seed not having been inspected or certified. As a result, in 2020, NASC withdrew operating licenses for 103 seed companies.

Nevertheless, under the auspices of the National Agricultural Seeds Council Act (2019) the Nigerian government is paving the way for "the deployment of private or authorized seed inspectors to complement NASC seed inspectors" (Mabaya, Ajayi, *et al.*, 2021, p. 18). While the regulations state that only certified seed can be sold in Nigeria, the sale of small quantities of uncertified seed has been tolerated in the informal sector (Bentley *et al.*, 2020).

With regard to VPCs, the cassava seed trade is growing, so certification is becoming more viable. However, while NASC is supposed to inspect seed to be certified three times a year, in practice they do not have the capacity to do so. If farmers want their seed certified, they have to pay transport costs for seed inspectors. A programme called *Building an Economically Sustainable Integrated Cassava Seed System in Nigeria project (BASICS)* has been providing logistical support to inspectors in some states, so that village seed entrepreneurs can have their seed certified; however, this is costly, so options are being explored for "local community third party certifiers" (Bentley *et al.*, 2020, p. 845). A Cassava Seed Tracker, a digital tool, has been introduced to enable this process.

With regards to yam, many new propagation technologies are being implemented, each of which requires certification (Maroya *et al.*, 2022). A consultative process has taken place in which the criteria for yam certification schemes have been revised as part of the work undertaken through Yam Improvement for Income and Food Security in West Africa (YIIFSWA). However, the system requires that both foundation seed and certified seed are inspected three times – before the seed is

planted, three to four months after planting and at the harvesting stage. To facilitate this process a digital Yam Seed Tracker has been introduced, which will be discussed more below.

Apart from the SeedTracker™ technologies, Nigeria has also introduced a SeedCodex system for seed traceability and authentication, which is discussed later in this report.

4.1.5 Tanzania

Tanzania's regulatory mechanisms and structures for seed production, certification, variety release, marketing, packaging, labelling, and plant property rights are well established in the *Seeds Act 2003* and the *Plant Breeders Rights Act 2012* (AGRA, 2019). All seed producers, growers and dealers in Tanzania – including small-scale farmers or groups of small-scale farmers – must register with the Tanzania Official Seed Certification Institute (TOSCI) (United Republic of Tanzania, 2020). Like the other countries in this report, the largest part of the seed sector is informal, but some producers are adopting certified seed.

Four crops cover 58% of the land on which cereals, pulses and oil crops are produced: maize, rice, bean, and sunflower crops (Mabaya, Mizambwa, *et al.*, 2021). Maize and rice are the main staples of the country and cover 4.9 million ha and 1.7 million ha respectively. Beans are the main source of protein for most households, and in recent years, "sunflower has gained prominence as an industrial crop that offers a reliable source of raw material for edible oil processing factories" (p. 1). Seed production and variety maintenance is constrained by inadequate funds and infrastructure, and insufficient time is given to training and mentoring breeders to ensure continuity between breeders retiring and newly hired breeders, resulting in early-career breeders being inexperienced and less productive.

The *Seeds (Control of Quality Declared Seeds) Regulations 2020* outline the procedure for registering, inspecting, sampling and testing seed, as well as seed packaging and labelling (Mabaya, Mizambwa, *et al.*, 2021). Despite the insistence that seed dealers be registered, currently only 15 seed dealers have been registered. According to the regulations, QDS seed must also be multiplied only with formally registered open-pollinated varieties, which does not account for the VPC seed sector. QDS producers and growers are responsible for quality control of their own seed, but must undertake several measures, outlined in the regulations (United Republic of Tanzania, 2020, sec. IV), including appropriate soil quality, quality production procedures, seed inspection and testing, and record-keeping. Once the QDS seed producer, grower or dealer has received satisfactory field and laboratory results, they notify TOSCI and can proceed to sell the seed in closed labelled bags or containers. Further tests must be conducted every seven months to ensure that seed labels reflect the percentage of germination of the seed.

Decentralised VPC seed production

The main VPC discussed in the literature for Tanzania is sweetpotato, however, access to quality seed is low due to various bottlenecks and farmers are forced to rely either on saving their own seed or acquiring planting material from neighbours, family and friends (Okello *et al.*, 2015). The lack of planting material leads to delays in the planting time and limits the area that can be planted (Namanda, Gibson and Sindi, 2011).

In a project that examined the impact of changed production methods, instead of the introduction of improved seed, groups (72%) or individual (28%) farmers were trained in multiplying and distributing quality sweetpotato planting material (McEwan *et al.*, 2017). After a year, 69% of decentralised vine multipliers continued multiplying vines, but less than half still used the seed production technologies promoted by the trainers and only 48% were still multiplying seed for sale. However, women's groups were more likely than other farmers to have continued with the practices and reported gaining skills and confidence in using the new technologies. Furthermore, new skills were adopted when they were "adapted into existing technical practices and social systems" (p. 69), thus indicating that social factors are critical to the sustainability of vine multiplication efforts. For example, when farmers were aware of methods to conserve vines during the dry season and the reason for doing so, they generally implemented these techniques (Okello *et al.*, 2015). However, they did not necessarily adopt all the techniques of which they were aware but usually adopted 1-3 depending on the agro-ecology of the area in which vines were being conserved.

These studies suggest that even though providing planting material for improved varieties is an important intervention, other possibilities for improving sweetpotato seed production can also be deployed.

Devolution of VPC seed inspection

TOSCI employs 45 (29 male and 16 female) seed inspectors across the country, but it acknowledges that more inspectors are needed to undertake the required seed inspection activities (Mabaya, Mizambwa, *et al.*, 2021). It has also drawn from a pool of public extension officers in local government authorities and trained them in seed inspection, but because they are also assigned other duties, they have not been adequately able to deliver effective inspection services. While private companies may now train and employ their own seed inspectors, so far TOSCI has not registered any (Kuhlmann and Dey, 2021; Mabaya, Mizambwa, *et al.*, 2021).
Both certified seed and QDS seed receive inspections, but fewer fields of QDS seed are inspected. Furthermore, the 2020 QDS regulations focus only on open pollinated plants, which may only be marketed within the specific ward where such seed is produced (Mabaya, Mizambwa, *et al.*, 2021).

Seed growers must notify TOSCI once they have planted their basic seed, and field inspectors will then visit the fields, ensure seeds meet the prescribed quality control requirement and standards, and thereafter submit a report to TOSCI who may register the seed dealer (United Republic of Tanzania, 2020). If their registration is declined, they can appeal to the Minister of Industry and Trade (Kuhlmann and Dey, 2021). However, Tanzania has "a low degree of stakeholder awareness concerning existing seed polices, laws and regulations", making implementation of seed policies and legislation difficult (Mabaya, Mizambwa, *et al.*, 2021, p. 18).

Small-scale farmers and their groups must approach the Chief Seed Certification Officer through the village and district authorities in the area where seed production is being undertaken in order to register as a QDS dealer (United Republic of Tanzania, 2020). Applicants must be able to show that they have basic knowledge of seed production (having gone through TOSCI training), have enough land (no more than 12 acres) and have suitable facilities for seed conditioning and storage. The village authority and district authority in the area where QDS seed is being produced must recommend the applicants to TOSCI. The application is then evaluated by TOSCI, which will register the applicant for three years if all requirements are met. However, TOSCI does not have sufficient resources to "effectively enforce the seed regulations" and awareness of the policies, laws and regulations is low (Mabaya, Mizambwa, *et al.*, 2021, p. 18).

Nevertheless, TOSCI has implemented "aggressive inspection and monitoring" of agro-dealer shops and has increased the "severity of punitive measures" – including the possibility of imprisonment – for dealing in counterfeit seed. In addition, as discussed later in this paper, TOSCI, in collaboration with the Tanzania Telecommunications Corporation (TTCL) and a seed label printing company, Queenswood, has introduced an electronic seed labelling system which allows label users to verify seed authenticity.

4.1.6 Malawi

The key policy instrument to ensure seed quality control in Malawi is the *National Seed Policy* (Ministry of Agriculture, Irrigation and Water Development, 2018). The bulk of the policy focuses on identifying policy goals, outcomes and objectives, and implementation arrangements. The main goal of the policy is to support the *National Agriculture Policy* in addressing and alleviating poverty and hunger, by ensuring seed quality that increases "crop production and productivity" (p. iii). The policy also seeks to align with other seed legislation in other countries in the region, especially the Seed Harmonization Frameworks of the Common Market for Eastern and Southern Africa (COMESA) and the Southern Africa Development Community (SADC).

The key priority areas are identified as the "institutional, regulatory and legal framework; seed certification and quality control information system for the seed industry; production of different classes of seed; biotechnology and biosafety research; seed marketing and distribution; seeds, orchards, and vegetative propagated materials; and integration of seed topics in the education curriculum"(Ministry of Agriculture, Irrigation and Water Development, 2018, sec. 3.0).
Furthermore, the policy argues that weak public-private partnerships have resulted in lack of internal quality control, seed certification services not being provided timeously and ultimately, poor

quality seed. Other problems include "low penalties on fake seed, restricted entry to seed warehouse, manipulation/tampering of seed samples and seed lots, altering confidential seed documents, and false advertisement and information" (sec 3.2). Data and information in the seed industry have also been inadequately handled such that it is difficult to retrieve and use the data and information (sec. 3.3).

While acknowledging the importance of "all concerned Ministries, Departments and Agencies, other public institutions, the media and many other seed industry stakeholders including Civil Society Organizations'' (Ministry of Agriculture, Irrigation and Water Development, 2018, p. iii), policy especially focuses on the seed industry. The policy foresees a situation in which more local seed companies receive certification and enter the market, and proposes lowering the cost of certified seed by (i) waiving duties and taxes on equipment and materials used in the seed industry; (ii) encouraging seed companies to sell different sized seed packages "to suit different categories of farmers depending on their land holding sizes and income levels"; and (iii) ensuring that farmers can access high-quality seed timeously (sec. 3.6). These measures are seen to increase the likelihood of all farmers purchasing quality seed, thereby increasing the size of the market for seed producers.

The policy only recognises informal seed to "the extent that it maintains known genetic purity and is produced under recommended conditions that maintain its genetic purity" (sec 1.1). Given the locally grounded nature of transactions in the informal sector, little data is available on seed performance, which are based in local social structures with embedded indigenous knowledge and standards (Mabaya, Kachule, *et al.*, 2021).

In terms of seed production, the National Seed Commission is tasked with (i) registering and monitoring the activities of seed producers and ensuring that the specified classes of seed are being produced; (ii) bulking pre-basic and basic seed for certified seed production; and (iii) ensuring that seedlings, roots, rhizomes, corms, stems, sprouts and leaf production for orchards and VPCs comply with quality control procedures and guidelines (Ministry of Agriculture, Irrigation and Water Development, 2018; Waliyar, Hoisington and Rhoads, 2021). But these seed systems are not functioning well (Waliyar, Hoisington and Rhoads, 2021).

Decentralised VPC seed production

Common VPCs grown in Malawi are potato, cassava and sweetpotato. Potato is an important cash crop, while cassava is the second biggest staple in the country after maize, while sweetpotato is grown for cash and consumption; even the leaves of the plant are eaten (Kathabwalika *et al.*, 2013; Mudege, Nyekanyeka, *et al.*, 2015; Kanyamuka, Dzanja and Nankhuni, 2018; Tione *et al.*, 2018).

Regarding the production and distribution of potato seed in Malawi, the seed system is poorly developed, even though it is an important cash crop for small farmers and Malawi is the second biggest potato producer in Africa after South Africa (Mudege, Kapalasa, *et al.*, 2015; Tione *et al.*, 2018). While research institutions are breeding modern seed varieties, testing, multiplying, releasing and distributing seed, the seed system remains mostly informal, and many consider it risky to buy potato seed at the market as it is difficult to establish the quality (Mudege and Demo, 2016; Tione *et al.*, 2018). In the informal system, farmers do not separate the production of potato seed and the production of ware potato (Mudege, Kapalasa, *et al.*, 2015). Rather, they choose ware potatoes that can be used for seed based on identifying healthy potato plants in their field that have no signs of disease for the next season of planting and marking unhealthy plants so that they are sure not to use those for seed potatoes.

In some instances, when new varieties have been introduced, they are given to a small number of farmers, who then pass the seed on to other farmers after harvest (Tione *et al.*, 2018). This seed pass-on program means that farmers do not have to pay for improved seed, so adoption of improved seed is not limited based on price. Further, the increased yields significantly influenced farmers to choose improved seed varieties.

In a project which aimed to improve potato seed production in Malawi, men formed seed production groups, were provided with foundation seed, and learnt techniques for multiplying seeds on small plots, including proper spacing to ensure the seed tubers grow large enough (Mudege and Demo, 2016). Even though yields increased, many poor families purchased food rather than seed and some women said they "sometimes knowingly buy bad seed because it is cheap" (p 156). Further,

the demand for improved seed outstripped demand and decentralised seed multiplication by smallholders did not increase the availability of disease-free, quality planting material.

With respect to cassava, productivity has been increasing due to improved seed being introduced, however, productivity is still constrained because farmers over-reuse seed and their farming practices are inadequate because of poor access to extension services (Kanyamuka, Dzanja and Nankhuni, 2018). In 1991/2, the Malawian government undertook a small-scale cassava multiplication scheme, but the varieties introduced were not favoured by farmers so farmers were slow to adopt them (Alene *et al.*, 2013). Indications are that farmers prefer their local varieties, so a decentralised approach is needed to improve the varieties that farmers prefer (Moyo *et al.*, 2004).

Malawi is the biggest sweetpotato producer in Africa (Hummel *et al.*, 2018; Okello *et al.*, 2018). After cassava, it is the most important food security root and tuber crop (Mbewe *et al.*, 2021). As for the other VPCs, sweetpotato farmers also recycle considerable amounts of planting material and as a result, the incidence of disease being spread by sharing seed is high. The main improved varieties that have been promoted in the country are orange-fleshed sweetpotato (OFSP), mainly because they contain high levels of beta-carotene, which is a good precursor for Vitamin A (Hummel *et al.*, 2018; Mudege, Kebaara and Mukewa, 2019; Mbewe *et al.*, 2021). These improved varieties have been widely distributed throughout the country and overall country yields of sweetpotato have increased – more so than in other African countries (Okello *et al.*, 2018). However, due to lower dry matter content, the roots of some OFSP varieties are more highly-perishable, which lowers their market value (Moyo *et al.*, 2022).

Many households prefer non-OFSP sweetpotatoes based on sweetness and starchiness but when they are aware of the health benefits, they are more likely to adopt OFSP – even though as producers they would rather sell OFSP than eat it (Hummel *et al.*, 2018). Where research centres provided clean seed, disease prevalence was lowered and the seed helped to manage viruses, suggesting that this is a viable approach to improving sweetpotato farming in Malawi (Mbewe *et al.*, 2021). Regarding decentralised vine multiplication, women found the vine multiplication to be labour-intensive and thus preferred to undertake it in groups, which had the knock-on effect that those who had fewer farming resources (e.g. irrigation and land) also had access to multiplied vines and planting time (Mudege *et al.*, 2018). Even so, new technologies were not always adopted, and women said that lack of access to markets that preferred OFSP led to them falling back on non-OFSP farming.

However, demand for OFSP varieties is improving and commercial bakeries are switching to sweetpotato puree to replace white flour in bread and other baked goods (Moyo *et al.*, 2022). Due to the improved taste, aroma, soft texture and colour of such bread, it has become a widely eaten product. Further, the bakeries are encouraging farmers – especially women – to become decentralised vine multipliers (DVMs), thus boosting employment for women and youth in the communities where farmers are contracted to the bakeries, and also encouraging farmers to keep their crops disease-free. The production of baked goods using OFSP is also leading to Malawi needing to import less white flour and thus reserve foreign currency. Further, farmers have been trained to identify plant diseases and a "strong, entrepreneurial sweetpotato seed system has evolved" (Moyo *et al.*, 2022, p. 158). Farmers are being supplied with disease-free early generation seed, multiplying it in DVMs; the vines/seeds are heavily subsidised by government and government-employed extension officers are also involved in managing inspection.

Devolution of VPC seed inspection

No measures for decentralisation of seed quality assurance are suggested in the *National Seed Policy* and most of the measures discussed fall under the ambit of the National Seed Commission. As stated in the implementation plan, to enhance seed quality assurance to improve the performance of the agricultural sector, the National Seed Commission was to "disseminate messages on seed production, handling and distribution" to stakeholders and strengthen links between stakeholders in the industry (Ministry of Agriculture, Irrigation and Water Development, 2018, p. 17). To this end, the Commission was tasked with developing a communication strategy including the following: (i) awareness-raising campaigns in mass media and holding open days and meetings; (ii) setting up a web-based database and variety catalogue; (iii) a website inventory of all public and private stakeholders in the seed industry, to facilitate communication with these stakeholders and to ensure it could perform its seed quality monitoring activities; and (iv) media

campaigns, open days and meetings highlighting the disadvantages of "over-recycling seed beyond their genetically recommended period" (p. 19) and giving information about seed technology (p. 23). However, it is unclear when VPCs have been targeted: most of the attention given to seed inspection is for maize, bean, groundnut and soya bean, with inspection of other crops delayed or neglected (Mabaya, Kachule, *et al.*, 2021).

While the launch of a national seed commission is planned to "include representatives from seed companies, farmer organizations, agricultural research institutions, universities, and other related ministries and departments like the National Commission for Science and Technology" this will only be finalised when the new Seed Bill is passed (Mabaya, Kachule, *et al.*, 2021, p. 19). Nevertheless, in partnership with UKAid's initiative on transparency and accountability to improve economic development and service delivery, the government and Seed Trade Association of Malawi are planning to pilot a seed packet labelling system for guaranteeing seed authenticity, similar to those in other countries discussed above.

4.1.7 Zambia

Unlike many other African countries, agriculture only makes up a small part (9.2%) of the Zambian gross domestic product (Kuhlmann, Zhou and Keating, 2019). However, two-thirds of households and 85% of the population are involved in the sector. A wide range of staple crops are grown in the country (including corn, sorghum, rice, peanuts, sunflower seeds, vegetables, and cassava) but about 75% of crops produced annually are maize and cassava. Seed breeding centres on hybrid maize, but also includes rice, groundnut, and beans, with little attention paid to VPCs.

Zambia's regulations governing the seed sector include the *National Seed Policy* (1999), the *Plant Variety and Seeds Act* (Cap 236; Seeds Act), *Plant Variety and Seeds Regulations* (amended in the *2006 and 2018 Seeds Regulations*), and the *Plant Breeder's Rights Act* (no. 18 of 2007). The *National Agricultural Policy* also includes many regulations on seed (Kuhlmann, Zhou and Keating, 2019). The policies focus on shifting towards a liberalised seed system, ending government parastatal seed production and marketing (Mabaya *et al.*, 2019). The private sector played a key role in drafting the new seed regulations but civil society organisations have objected that the regulations do not adequately address the needs of smallholder farmers (Kuhlmann, Zhou and Keating, 2019).

Research organisations which produce foundation seed for new crop varieties rely on registered seed companies to multiply the seed and market it, although they typically oversee early generation of seed (Kuhlmann, Zhou and Keating, 2019). However, many companies also produce their own foundation seed (including 78% of private sector maize seed producers, 50% of private sector rice seed producers, and 33% of private sector bean seed producers) (Mabaya *et al.*, 2019). Of the 50 registered seed companies, 17 focus on the four priority crops, but only ten of them produce certified seed: the remaining seven produce QDS seed. The other 33 registered seed companies are seed merchants and do not produce seed themselves. Farmers have challenges trying to certify their own varieties, even if they are high quality and have high commercial value because they "tend to be diverse and constantly evolving", making it difficult for them to pass the DUS test (which requires uniformity and distinctness) (Kuhlmann, Zhou and Keating, 2019, p. 13). Hence, there would be the scope to formalise more seed production if the legal framework were to allow for a new system to track and record local lineages (such as gene fingerprinting). Even when farmers are using certified seed, most seeds chosen are not new varieties: the typical variety age for maize is ten years; for rice, four years; groundnut, 29 years; and bean, 12 years (Mabaya *et al.*, 2019). Some varieties of groundnut have been available for 62 years, and many of the most popular maize varieties are more than 20 years old.

Decentralised VPC seed production

The only VPC mentioned in the literature on Zambian seed systems is cassava, which is the second most important food crop after maize and the primary staple crop in the northern part of the country (Szyniszewska *et al.*, 2021). Smallholders typically grow more than one field at a time to guard against crop failures and mostly rely on their own material cuts that are immediately replanted or from planting material they have stored. They often do not have a good understanding of the diseases affecting these crops, and few take measures to limit crop diseases. Only a small amount of planting material is taken over a greater distance – including a few transactions of large

sums of money. Typically, only those living close to markets have adopted improved varieties and most rely on friends, family and neighbours for information about growing these crops (Szyniszewska *et al.*, 2021).

Devolution of seed inspection

Zambia has 118 licensed seed inspectors, 83 of whom are in the private sector and a further 35 employed by the Seed Control and Certification Institute (SCCI) (Mabaya *et al.*, 2019). Seed inspectors can be licensed once they have completed a diploma in agriculture and passed the SCCI's seed inspectors training course. They are expected to "perform seed quality control services such as seed inspection, sampling, and analysis" (p. 4) and decentralised and devolved inspection is helping with the process of seed development and evaluating new varieties. Apart from inspection and certification of seed breeding and production, Zambia is also introducing security features on seed labels, although this effort is currently under-resourced.

Zambia does not have specific standards for VPCs. An interviewee and former employee of the Seed Control and Certification Institute made several comments on this. (Interview, 12 August 2022): (i) Just as grains already have their own regulations, so the VPCs seed could have their own regulations and procedures; (ii) legumes could be grouped as VPCs because most of them are self-pollinated; (iii) few companies are interested in doing VPC seed production commercially, as farmers can self-produce these seeds. In contrast, people are forced to buy maize hybrid seed every planting season as this seed can only be produced by commercial seed companies.

4.2 Accredited inspectors

Each of the seven studied countries have accredited inspectors in place. In each country, these are at different levels, but generally, they include district agricultural extension officers and trained and authorised agricultural experts. We illustrate below how they operate in each of the studied countries.

In Ethiopia, while inspectors were found at regional level, many had limited technical capacity, and even when they had the technical capacity, the area they were expected to cover is too big an area (Hassena, Broek and Borman, 2020). Given the area they were expected to cover, transport was often unavailable; old equipment was often in need of repair and staff had not been trained on new equipment. With respect to potato field inspection, mobile phones enabled the easy delivery of disease and pest control information, but it also meant that farmers knew when inspectors were coming and could conceal any infestations (Tafesse *et al.*, 2020). Further, the different role-players interested in quality control, including farmers, NGOs, government decision-makers and inspectors, had different ideas about which solutions should be deployed to address problems; this was also aggravated by information asymmetries and power imbalances (Damtew *et al.*, 2018). As such, many government regulation officers believe that regulations and procedures are not being adequately applied (p. 17). While Ethiopia has elaborate standards and regulations, implementation remains a challenge.

While the country does not accredit private inspectors (Interview, 18 May 2022), in the case of potato seed production, committees from seed producing cooperatives inspect and supervise seed potato fields to limit the occurrences of disease; but government inspectors complain that these committees are under-qualified and have poor capacity, so the inspection burden remains with them (Damtew *et al.*, 2018). However, seed producers complain that government inspectors are not undertaking their work in time to ensure they can sell their seed on the market. Therefore, it is necessary to facilitate joint learning and "improve the knowledge and technical capacities of potato growers and experts on the diagnosis, monitoring, and management of the two diseases" (Damtew *et al.*, 2018, p. 17). According to the ATA (2016, p. 67), managing seed inspection has become more difficult since more smallholders are multiplying seed, "resulting in smaller and more dispersed seed production plots", with field inspectors having to spend a lot of time visiting smaller sites.

Similarly, for cassava seed inspectors in Nigeria, inspection was limited by "too few inspectors and facilities, limited technical capacity, long travelling distances between inspection sites, and prioritization of other crops such as maize and rice over cassava" (Wossen *et al.*, 2020, p. 25). As discussed above, in 2020 there were only 60 seed inspectors in the country and although the

Nigerian government intends to deploy private seed inspectors "to complement NASC seed inspectors" (Mabaya, Ajayi, *et al.*, 2021, p. 18), no up-to-date analysis of the numbers, progress and impact could be found in the literature.

In the case of Uganda, the National Seed Certification Services (NSCS) are responsible for certifying seed and aim to undertake seed inspection by having cassava seed multipliers and sellers pay for inspection services (Awio *et al.*, 2019). In one study area, because the farmers saw the benefit of this, most (63%) were willing to pay for the service, although the amount they were willing to pay depended on whether the inspector was coming from district offices or the NSCS head office.

Tanzania is much more advanced in terms of training accredited inspectors for VPCs, especially for cassava. Two interviewees explained that they have offices at the zonal level so it is expensive for proper TOSCI qualified officers to inspect seeds; it is much cheaper for seed producers to do so. In Kenya, decentralized QA seed inspection has been centralised under KEPHIS. Private sector inspectors are now being trained and deployed by KEPHIS, but these numbers are still low (Waithaka *et al.*, 2019) and we could not find any literature that evaluates this program.

4.3 ICT platforms for e-certification

While no references were made to e-certification in the case of Ethiopia, the other countries in this study were already using or planning to use ICT systems. According to several interviewees, the use of ICT platforms is assisting regulatory agencies, farmers' associations and seed-producing companies to reduce the time needed to secure inspection, make payments and receive certificates.

For example, in Nigeria and Tanzania, SeedTracker™ – a SeedTracker™ digital tool for seed system development – has been piloted by TOSCI and piloted and adopted by NASC (Bentley *et al.*, 2021). The tool was piloted for cassava seed systems through the BASICS project in Nigeria and as part of the Building an Economically Sustainable Seed System in Tanzania for Cassava (BEST Cassava) project in Tanzania. TOSCI and NASC are interacting so they can learn from each other's experiences of using the tracker. The tracker is "usable on any internet-enabled device and offers real-time tracking of the seed production database, generates geographic maps, and offers analytics" (Maroya *et al.*, 2022, p. 440). The software can be used on a smartphone or any other internet enabled device (web-based technology) (Bentley *et al.*, 2021). The information can be used for business, e. g. to connect buyers and sellers of seed. SeedTracker™ can also be used by seed regulatory agencies, to facilitate electronic certification of vegetatively propagated seed (www.seedtracker.org/cassava; Ouma et al., 2019). It is tailored to meet regulatory processes for quality assurance and seed certification, registering seed producers and fields, arranging seed inspections and registering seed yam actors across the value chain (Maroya *et al.*, 2022).

In Nigeria, the tracker is helping inspectors and NASC organise information about seed production, enabling them to monitor and certify seed, achieve digital integration of the seed value chain, and build capacity in NASC (Kumar *et al.*, 2020). The tool has been piloted for cassava seed systems through the BASICS project since 2017, and has been used as formal platform for registration of all classes of cassava seed producers; as of 2022, over 10001 000 cassava seed fields were registered and certified using SeedTracker™. In 2019, NASC adopted it as a national platform for e-certification. The tracker is useful for producers who want to register their seed and create a seed inventory, for regulators who need to ensure seed certification traceability and keep a seed inventory, and for buyers who want to access a list of seed producers from whom they can purchase seed.

The tracker is also gaining traction in Tanzania seed regulatory agencies, albeit with some concerns. In an interview on 3 August 2022, one interviewee said that SeedTracker™ needed to be more customisable and user-friendly, allowing users to access it and create accounts without registering with IITA. The tracker was deliberately designed to ensure seed inspectors were verified and certified before they could input/capture data; nevertheless, the interview highlights the need to explore using more context-specific technical terms and language within the app.

Tanzania and Nigeria are also working together on a prototype of SeedTracker™ for yam (Ouma *et al.*, 2019). This uses an Open Data Kit (ODK) – an open-source suite of tools that allows developers to build digital information services on the Android smartphone platform. The tracker aims to help

researchers gather information more efficiently by reducing the amount of time needed to collect, enter and record yam seed data in the field. It also aims to ensure other stakeholders can access information about *inter alia* seed yam costs, pest and disease surveillance, and the availability of quality certified materials. Users consider it effective for its standardised data input, quick access to data, ability to produce data visualisations rapidly, and ability to record geolocations with the data. Therefore, seed sector stakeholders are able to access information more quickly to aid decision-making.

In addition to the seed trackers, several countries have introduced electronic labelling. For example, Nigeria has introduced a SeedCodex system, which creates digital, coded seed labels under a scratchable veneer (Tech Gist Africa, 2019; Mabaya, Ajayi, *et al.*, 2021). When the veneer is scratched off, the code becomes visible, and buyers can send the code in a text message to a designated phone line; the sender will then receive confirmation if the seed is authentic. So far, the system has only been rolled out for cassava crops, but more crops are expected to be included over time. Kenya has similar secure seed labelling technology to limit the spread of counterfeit seed and authenticate seed quality (Waithaka *et al.*, 2019). Even though many seed companies have been using the new labels, however, so far, farmers are lacking awareness and not activating the labels by sending the code to be verified. Uganda has a similar seed labelling technology – the Seed Tracking and Traceability System (STTS) – deployed in September 2021 (Mabaya, Waithaka, *et al.*, 2021). It operates as a partnership between government and the private sector, including USTA, but since it is a new project, we could not find research on the impact of the system. TOSCI has also adopted a similar system in Tanzania (Mabaya, Mizambwa, *et al.*, 2021), with one of the interviewees (Interview, 8 July 2022) stating that it was seen as a way to ensure that unscrupulous seed traders could not tamper with labelling.

4.4 Seed producer associations

Experts, seed producers, trader cooperatives, organisations and associations exist in all the countries in this study, however, the literature review yielded far more detail about the seed producer cooperative systems in Ethiopia than for the other countries, where limited information was available about such organisations, especially the role of these organisations in VPCs. These organisations undertake various activities, but mainly represent the private sector in advocating for a better regulatory environment and for regional harmonisation of seed laws and regulations (Waithaka *et al.*, 2019). They also work with government seed inspection services (especially in trying to stamp out counterfeit seed), plant health services (to respond to emerging pests and diseases), and link members to regional and international organisations that work in the seed sector.

For example, STAK was formed in 1982 to be an umbrella organisation for the private sector seed industry in Kenya (Waithaka *et al.*, 2019). It has 38 members, many of whom are happy with the performance of the organisation in advocating on behalf of the industry, but many of whom are also concerned that it does not providing sufficient value to producers, because it rarely reaches out to members to establish their concerns, priorities and expectations. STAK also struggles to mobilise resources for the work, has weak managerial ability, and board positions are dominated by men.

The Tanzania Seed Trade Association (TASTA), established in 2002, links Tanzania's private sector seed industry with the government and represents the voice of the private seed industry on various platforms (Mabaya, Mizambwa, *et al.*, 2021). It has 49 members, including local, regional and multinational seed companies, and has an eight-member board. TASTA's membership has been growing and members are satisfied with the association's performance, because it has had success in liaising with government "for the removal of VAT on seed packaging materials, facilitated seed companies' efforts to license public varieties, and has also played a key role in lobbying for TOSCI's application for ISTA accreditation" (p. 19). Other crop-specific seed associations also exist. For example, the cassava seed producer's association *Chama cha Wazalishaji mbegu* (CHAWA) has supported existing and aspiring cassava seed entrepreneurs through the BEST programme (Mwakanyamale *et al.*, 2021), and is reportedly performing well in bringing together farmers and helping them secure seed inspection at a reasonable cost. However, membership and participation fees are too high for some cassava seed entrepreneurs, and men appeared better able than women to make use of the connections provided by CHAWA to establish relationships with input suppliers.

Hence, CHAWA needs to "explore ways of reducing or eliminating barriers to membership, especially for female CSEs", (Mwakanyamale *et al.*, 2021, p. 20).

In Malawi, the Seed Trade Association of Malawi (STAM) was established in 2004 and by 2019 had 24 members (private sector seed businesses). The association's main mission is to "deliver a steady stream of new seed varieties to smallholder farmers at affordable prices through an expanded network of agro-dealers" (Mabaya, Kachule, *et al.*, 2021, p. 22). Seven elected board members hold offices for a term of three years, and the secretariat consists of a CEO and support staff (with some positions still unfilled). Only one board member and one secretariat staff member are women. Further, members argue that STAM needs to raise funds and undertake more roles, including lobbying government to enact the Seed Act, assisting members with defaulting agro-dealers who buy seed on credit, and facilitating more links between companies and farmers.

In Zambia, the Zambia Seed Trade Association (ZASTA) represents the interests of its 19 members, and play a key role in liaising between private sector seed companies and government in the FISP programme (Mabaya *et al.*, 2019). It also plays a role in educating members in aspects of production, extension, and seed policy (Kuhlmann, Zhou and Keating, 2019). Currently, the organisation is also looking at how it can be involved in seed labelling systems. For example, discussions are underway with the Zambia's Seed Control and Certification Institute (SCCI) about whether it could take the responsibility for printing labels for members' seed; members would then pay ZASTA to purchase the labels. Kuhlmann, Zhou and Keating (2019) also propose that ZASTA should play a role in educating and training agro-dealers to ensure the bolstering of numbers of agro-dealers, and also train agro-dealers and farmers to identify uncertified and counterfeit seed.

One former SCCI employee interviewed in this study believes that it is ideal to have strong and functioning farmers' associations which can organise farmers to pay for inspection services; however, that such arrangements cannot work effectively with a centralised inspection system, so until the inspection services are fully decentralised, farmers' associations cannot easily arrange for VPC seed inspectors to visit farmers' fields under the auspices of the farmers' association (Interview, 12 August 2022).

In Uganda, as already explained above, USTA has been involved in the rollout of electronic seed labelling in the country. Established in 1999, it has 33 members, all private sector seed producers, and three associate members who offer seed services such as seed testing and input distribution (Mabaya, Waithaka, *et al.*, 2021). USTA's members that are locally registered seed companies "produce crop and vegetable seed for local market and surplus for export to the neighbouring countries" (Longley *et al.*, 2021, p. 41). The association's main activities, besides its involvement in seed labelling, is advocacy to create a seed regulatory and policy environment that supports its members. It enjoys a close relationship with the Ministry of Agriculture and due to its efforts, Ugandan seed law was harmonised with COMESA, so its members can now trade with other members. USTA has a seven-member executive committee, each of whom serve for three years; two positions are currently held by women; the low number of women is "largely structural, emanating from the overall low participation of women as managers/owners of seed companies" (Mabaya, Waithaka, *et al.*, 2021, p. 23).

In Nigeria, the Seed Entrepreneurs' Association of Nigeria (SEEDAN), formed in 1992 and registered in 2012, is an umbrella association of seed companies (Mabaya, Ajayi, *et al.*, 2021). It currently has 73 members and a 15-member board (one woman) elected in 2008, but only one staff member due to its shortcomings in raising resources to fund a secretariat. Unfortunately, we could not find any further literature on this seed association.

In Ethiopia since 2007, hundreds of seed potato cooperatives have been set up (Tadesse *et al.*, 2020; Tafesse *et al.*, 2020). For example, in the potato seed sector, they produce more than 20% of the national seed demand (Tafesse *et al.*, 2020). Cooperative seed production is being promoted because the public sector has not managed to develop a sustainable potato seed sector that can efficiently provide farmers with quality seed of improved varieties (Tadesse *et al.*, 2020). Further, potato seed production has been shown to empower women's farmer groups. In some parts of Ethiopia, farmers' research groups (FRG) and farmers' field schools (FFS) have been set up, supported by EIAR, and these farmers have become specialised seed potato growers (Hirpa *et al.*, 2010). While the seed tubers they produce are better quality seed tubers than other farmers, they "may still not be of standard quality" (p. 540). To remain successful, cooperatives need to organise pooled labour for farming activities, and be provided with "improved seed, construction materials

for building improved seed storages and training in agronomic and storage practices by extension professionals" (Tadesse *et al.*, 2020, p. 151). Caution is also needed that when sharing equipment among members, they do not inadvertently spread disease (Tafesse et al., 2020).

However, these cooperatives have not received much support or guidance in many parts of the country, as they have no handbooks to guide them in quality assurance, are understaffed, and lack disease monitoring skills (Tadesse et al., 2020). In some cases, monitoring committees felt they had not received enough training to be effective, for example in identifying latent disease and implementing containment methods. They also said they needed more support from extension officers and researchers. Some farmers in the cooperatives also felt that given the shortage of land it was almost impossible to meet the quality standards for QDS. They also have not received much guidance from local governments, who are meant to provide guidance on seed production and seed quality maintenance, such as "threshold values for number of diseased or wilting plants in the field or affected tubers in storage … [and] rules for the disposal of rogued plants … in relation to financial compensation for the affected producers" (p. 152).

Overall, the assessment from these studies and interviews with practitioners in these countries shows that seed producers' cooperatives/associations know the importance of monitoring fields but that decentralised seed inspection can only be viable with much more support from the central governments and training from public and research institutions such as CGIAR. Nigeria has very strong farmer associations for VPCs, especially cassava and yam.

4.5 VPCs novel disease diagnostics

During interviewees with seed regulatory officers and researchers in the seed sector we observed that few countries are using novel disease diagnostics for VPCs. Interviewed experts mentioned a few tools they were using but it was hard to understand what tool exactly they were referring to. Nonetheless, it was clear from CIP researchers in both Ethiopia and Uganda that they are experimenting with a loop-mediated isothermal amplification technique (LAMP). In Uganda CIP introduced and piloted the use of LAMP, which was recently validated in the country as a cheap disease diagnostic tool (Interview, 24 June 2022). This is an important area for further research in VPCs innovative approaches.

4.6 Other novel approaches

There are several other novel approaches used in the VPCs. Some of these include the QDS application and adopting successful and productive and efficient techniques. Based on the answers supplied by the 18 officials who responded to the online survey, only five countries have separate QDS standards, five do not have such guidelines, three countries are using the same standards used for other crops, and four did not answer the question. During the follow-up interviews, we learned that VPCs QDS is used in Ethiopia, Nigeria, Tanzania, Uganda and Zambia, but not in Kenya and Malawi. While the Kenyan seed laws do not permit the use of QDS, in Malawi, one interviewee explained that his country was seed self-sufficient and he wondered why other countries are using such seeds (Interview, 5 July 2022). In countries where QDS are allowed, not all seeds are inspected. For instance, for Tanzania, the rule is that only 10% of the field should be inspected – this is what is stated in the guidelines (Interview, 5 August 2022).

Using a multi-stakeholder approach is useful in bringing all stakeholders onboard and in ensuring that every actor in the sector is fully engaged and that experiences, technical know-how, knowledge and skills are shared. Interviewees from Uganda and Tanzania explained how important it was for them to work directly with the seed regulatory agencies for them to achieve a bigger and quicker impact and change. In Tanzania, IITA worked with NGOs for some time, but it was only when they worked with government agencies that they were able to effect policy changes including the piloting of a new cassava seed variety and seed tracker (Interview, 5 August 2022). It was on this basis that from 2013, TOSCI and the Tanzania Agricultural Research Institute, through funding support from the Bill and Melinda Gates Foundation and with technical support from IITA and Mennonite

Economic Development Associates (MEDA), were able to develop a seed inspection and certification protocol for cassava seed in Tanzania.[2]

Novel approaches to capacity-building can be deployed. For example, a pilot project in Uganda targeted individual potato farmers with two ICT-mediated videos providing information about how to maintain the quality of existing seed stock, while also upping potato seed production and introducing improved varieties (Vandevelde, Van Campenhout and Walukano, 2021). Through these videos, farmers were informed about how to improve seed selection, seed storage and handling. The project was successful in that about 60% of farmers who watched the video remembered specific topics from it, not just general content. Further, the video on seed selection "led to increased awareness and subsequent adoption of practices shown, as well as a higher probability of using hired labour and of buying potato seed on the market," resulting in higher yields (Vandevelde, Van Campenhout and Walukano, 2021, p. 524). Information from the videos also spilt over to other farmers in the district.

Legislation and policies need not only be undertaken at the national level: bylaws can also help ensure seed quality. With respect to sustainable crop intensification in potato growing, some decentralisation has taken place in Uganda in terms of farmers' associations adopting formal and informal bylaws (Henry, Kibwika and Nampala, 2022). These bylaws focus on potato production as a cash crop. They are simple rules that have evolved over time and have the advantage that whereas government agricultural policy provides general guidelines, these bylaws focus specifically on potato cultivation and operationalise government policies to be effective and sustainable. Importantly, the bylaws do not only focus on the technical aspects of cultivation but also on the relationships between farmers, including boundary demarcation and conflict resolution. However, the goals are typically to increase production, gain "higher yields on smallholder farmland … minimise environmental costs and maximise sustainability … [and encouraging] appropriate agricultural techniques" (Henry, Kibwika and Nampala, 2022, p. 2). In a case study of two counties in southwestern Uganda, researchers found that both informal and formal bylaws had a role to play, but many of the formal bylaws were related to seed quality, setting boundaries on resource use, monitoring resources and users, coordinating activities, conflict resolution and issuing sanctions. Informal bylaws played a significant role in terms of permission to graze, preventing dumping, and harmonising costs and benefits. While this model was used for potato production, and not seed production, it provides a useful example of how quality assurance in production processes could be devolved to the local level.

4.7 Drivers of change

In the countries studied, there are a few issues driving change in VPCs' novel approaches, but the main driver is changing circumstances. There are three main factors in this. The first factor is the need to improve efficiency and quality. For example, while in Malawi seed testing and certification labs were established long ago, the major drive for decentralisation of inspection services is to ensure efficiency and improve quality. One interviewee explained that it is difficult to have people travelling all the way from the south to the centre of the country just to get their seeds inspected and thereafter certified. Therefore, the government's decision to establish zonal offices was part of the efforts to devolve inspection services and to improve efficiency in service delivery and to reduce timelines and cost incurred by VPC seed producers (Interview, 5 July 2022). From Tanzania to Zambia and from Kenya to Malawi, the shortage of staff in regulatory agencies and increasing demand for their services have made the decentralisation of their services to lower levels of the government imperative. To address the shortage of public staff, hybrid companies are mandated to self-inspect their seeds. As piloting and studies continue on VPC novel approaches, it has become much clearer why countries have to adopt a decentralised VPC seed production and devolved inspection and certification systems. For example, in Tanzania, IITA is working on costing part of using TOSCI and district officials. Initial findings show that the district officials have the ability to go and conduct inspections during the day and return to their residences, so funds for night allowances

[2] For more information, see: https://mel.cgiar.org/projects/283/385/new-seed-policy-in-tanzania-for-cassava-explicitly-recognizes-the-special-qualities-and-challenges-of-planting-material-for-this-vegetatively-propagated-crop-vpc

are not needed as they would be if TOSCI officials travelled long distances to go to those areas. If district agricultural officials are linked to seed certification it also gives the district a strong sense of ownership and further enhances local ownership of the inspection process. Tanzania for example, has put a lot of power at the district level. Local governments have the budget and power to implement things on the ground, and therefore, it makes more sense for the VPC seeds to be produced and inspected at the district level (Interview, 5 August 2022).

The second factor which has led countries to adopt various novel approaches in VPCs is the stakeholders' uptake and push for VPCs' new and quality varieties, especially the farmer's associations and breeders. Interviewees from Tanzania explained that the most effective and winning strategy is the development of a farmers' decentralised network followed by a decentralised quality assurance system. This system allows farmers to contact inspectors who are close to them and therefore, they do not need to contact people in further away capitals. Like farmers' associations, seed breeders are also keen to adopt new technologies in the seed sector and are able to influence changes through their formal advocacy channels in breeders' associations (Interviews, 3 & 5 August 2022).

The third and most important factor is state investments in the VPC seed sector. It must be acknowledged that in every country the government invests in seed security and managing the seed security of farmers and food. Indeed, this is the most strategic investment because governments' interests all over the world are to protect farmers' and consumers' health. And while for commercially sound and viable crops like hybrid seeds private companies have all incentives to invest in seed breeding businesses, for less commercially viable crops like VPCs it is unlike to get more investments from private companies, and it is therefore imperative for governments to invest in the seed development and inspection (Interview, 5 August 2022).

4.8 Gender and social inclusion in VPCs quality assurance

While some interviewees were not concerned about gender issues in getting novel approaches implemented in the country, some clearly explained that since VPCs are mostly produced by women, it is therefore important to have provisions and regulations which safeguard women's interests in inspections and certification of seeds. Literature also shows that in all seven countries, except in some parts of Ethiopia and Nigeria where due to cultural reasons sweetpotato is grown by men, the crop is largely grown by women (McEwan, 2016).

Unlike production of VPC seeds, the inspection of the crops is largely done by men since more men have been equipped with the relevant skills. Companies and even state regulatory agencies are largely focused on employing scientists with skills and have not given due consideration to upskilling women to be field inspectors. As one interviewee from Kenya explained, even for accredited inspectors, especially those from the private companies, they do not consider gender issues. For example, during its accreditation process of private or third-party inspectors, KEPHIS only ask companies to provide people they can train and certify. It is therefore incumbent upon companies to ensure that in their establishment they have women and men trained as seed inspectors (Interview, 29 June 2022).

The Malawian government is promoting a community-based approach to increasing potato production, partly because this has been shown to increase gender equality and women's empowerment (Mudege, Kebaara and Mukewa, 2019). However, in some projects, it has been noted that even when planting material is meant to be given to women, extension officers prioritise male farmers such that men receive fresher planting material and that they are more able to plant on time (van Vugt and Franke, 2018). In some OFSP projects, men even pushed women out of production and marketing because they feared women might earn more income than them and thus leave them out of decision-making (Kumwenda, 2018).

Many interviewees consider gender as a vital condition for ensuring equity in both decentralised seed production and devolved inspection systems, including in the VPC sector, but one interviewee cautioned against bringing gender in everywhere (Interviewee, 20 July 2022):

> *To have gender friendly VPCs standards is fine, but why do we have to bring gender here? Whoever is able to produce VPC seeds, let them do the job. It*

should be free to whoever is ready to do the job. It takes time to do women's and men's jobs.

This interview suggests that much more needs to be done to educate officials about why a focus on gender is important to create equal opportunities in seed decentralisation projects, and therefore why policy makers need to address women's access to land, irrigation, capital and training.

4.9 Challenges

From the online survey, we gathered several challenges to certifying VPCs:

i. Lack of specific regulations for VPC crops and standards, especially in the countries which are either still developing such standards and regulations, or entirely do not have such tools in place;

ii. Absence of crop specific certification guidelines and Standard Operating Procedures (SOPs), low capacity of the producers engaged in production of VPC, poor storage and handling facilities for seed;

iii. Lack of standards and distinctiveness, uniformity and stability (DUS) data;

iv. Inadequate experience, technical skills and training among the seed inspectors and certifying officials from state seed regulatory agencies, especially lack of staff specialised in certifying VPCs;

v. Limited understanding of the seed certification system by clients;

vi. Shortage of clean parent cuttings;

vii. VPC seeds are bulky, perishable, disease risks are high, and seed companies mostly are not interested in these crops; and

viii. Disease testing facilities are limited, and even those that are in place are not well known to staff from regulatory agencies.

Since most of the studied countries are in the early stages of testing, upscaling VPC seeds and/or planting materials of new varieties, with regulatory agencies also implementing newly formulated regulations and standards for inspecting and certifying VPCs, it is critical that respective governments and all other stakeholders invest in addressing the challenges highlighted above.

4.10 Needed resources and improvement on piloted novel approaches

From interviews and the literature review we find that every country has its own challenges and needs to improve existing and/or piloted novel approaches for VPC seed. We expand on these issues in the discussion section. Nonetheless, it is important to highlight that some of the key issues include building links between VPC seed regulatory agencies, between the current generation of seed producers and future generations, and building links between the regulatory agencies and farmers. For this to happen, governments and development partners need to invest in strengthening the capacities of regulatory agencies over a long period of time. The present dependency on short term projects like two-year projects is unlikely to bring significant changes if they are not sustained through long term plans. Projects piloted by research institutions need to be financed by public agencies to roll out successful VPC inspections and testing programmes.

In addition, the creation of impactful and durable platforms is needed to ensure the sustainability of novel approaches. Such platforms will enable the dissemination of information and the exchange of materials, experiences, and seeds. For example, the formation and empowerment of farmers associations is important for advancing advocacy about the value of purchasing quality materials.

5 Discussion

Ethiopia is the only country among the seven studied that does not have VPC inspection and certification standards in its seed laws and policies. However, in some countries, such as Kenya,

they only receive a mention and are not fleshed out; and in all countries the focus remains on grains, especially hybrid maize. Hence, it is important for all seven countries to pay more attention to the different characteristics and requirements of VPCs compared to open-pollinated seeds. Considerations should include seed production, the profitability of seed businesses, different institutional frameworks, and different standards. For example, while it is possible to have centralised hybrid maize seed production because maize seeds can be stored and transported in bulk to far-flung areas and easily distributed throughout the country, the same is not possible for VPC seeds or planting materials, which are highly perishable and heavier to transport. On this basis, IITA and CIP are interested in taking stock of existing novel approaches that various countries are piloting or implementing with the support of different projects supported by research and development partners.

Despite the slow adoption of VPCs regulations, six out of the seven studied countries are trying to implement a few potential approaches to decentralise seed inspection at farmer or grassroots level. It is likely that most countries will embrace a decentralised institutional framework to inspect seeds, not only because of the need to do so but because they are forced by circumstances like the persistent droughts that make seed availability almost impossible in countries like Zambia and/or in cases where diseases have almost wiped out crops such as banana in Uganda (The East African, 2009). Interviewees revealed that countries are realising that their seed inspection and certification authorities are handicapped by a shortage of both funding and professional staff.

5.1 Conditions under which decentralised QA mechanisms can work

Many African governments are encouraging private investments to devolve seed production and delivery to the private sector. However, these policies are mostly based on conceptualising a seed system that focuses on maize, soya, and commercial vegetables, while seed systems for VPCs have mostly been ignored. Despite the liberalisation of the seed sector, the private sector has so far not been the most efficient way to ensure the boosting of seed distribution and production: for example, it has only succeeded in delivering seed for maize, soya and commercially grown vegetables and has not produced seed for other major crops such as VPCs (Mausch *et al.*, 2021).

Various factors impact the efficiency of a privatised seed system. For example, (i) farmers do not always have access to information and cannot determine the traits and quality of any seed when they are ready to purchase; (ii) due to weak regulatory systems, low-quality producers find it easy to enter and exploit the market for short-term gains; (iii) lack of information and uncertainty about seed quality discourage farmers from purchasing commercial seed; (iv) due to uncertainty and/or lack of resources, farmers do not buy leading to seed companies facing low demand; (v) seed markets can be distorted by government input subsidy schemes or emergency seed relief programmes; and (vi) due to the protection afforded to intellectual property, some companies may gain a temporary monopoly, impacting on competitors (Spielman and McEwan, 2020).

Local seed production models are based on the assumption that the highest quality of propagation material can be more rapidly and efficiently provided to farmers when they are produced locally, especially in the case of VPCs that are bulky, perishable and difficult to transport across long distances (McEwan *et al.*, 2020). Specifically, a decentralised system that involves communities in seed production has been promoted as a way to involve farmers groups or individual farmers "as private entrepreneurs who could provide key connections between the formal and informal sectors" (p. 678). Such farmers are expected to purchase genetically pure and properly inspected planting material, which they can be trained to multiply using specialised seed production technologies. The evidence suggests that once farmers start producing improved cultivars of VPCs and exchange, sell or share planting material with others, the clonally propagated crops "maintain their improved traits", suggesting that for VPCs local production can be viable (Almekinders *et al.*, 2019, p. 31). The sustainability of these seed systems has been questioned (Mausch *et al.*, 2021). However, McEwan *et al* (2020) found that in Lake Zone, Tanzania, 60% of trained groups or individual decentralised vine multipliers (DVMs) had either sold improved sweetpotato vines in the year previous to the study (40%) or were using them on their own farms (20%); in addition, vines were gifted based on "empathy, altruism and building social capital" (p. 685). The study also suggests that individual DVMs (especially women) might be more successful than group DVMs.

5.2 Additional legislation, policies and amendments needed

As has been made clear in a range of literature before now, the legislation, policies and amendments to seed policy need to reflect the fact that seed policy for grains, cereals and some vegetables has different requirements than for VPCs. However, it is also important that within VPCs there are key differences, and so programmes that introduce improved seed will also need to be adapted to the specific crop; for example, while it is possible to replace all potato seed within one season, for bananas, farmers only replace plants as and when an existing plant dies. As such, plans for rolling out improved varieties for bananas will involve much longer timeframes. Furthermore, for banana crops, many more improved varieties are needed, based on the different end-uses and requirements of each existing non-improved variety; as explained above, many varieties of bananas are planted on one plantation, and farmers use specific planting patterns for different varieties. In countries where bananas are a staple crop, VPC seed standards need to be based on awareness of such differences, and not adopt a one-size-fits-all approach.

However, as noted when we discussed novel approaches above, national legislation and policy might not be sufficient when considering locally specific circumstances relevant to production and quality control. So, for example, local governments in collaboration with farmers' associations may need to formulate and enforce bylaws to ensure that production standards are maintained. Bylaws can be related to several matters, including technical aspects of seed production, land allocation, relationships between farmers and relationships between farmers and local government officials, environmental considerations (e.g. distance from water bodies), and land and resource allocation.

Because it is not possible to include every eventuality in a policy, it is better to set standards in a way that allows flexibility at local level. For example, because quality assurance is important for all stakeholders, policies should focus on creating an enabling environment for local-level collaboration between stakeholders, to jointly identify problems (such as pests and diseases) and find solutions. As such, policies should underscore that quality assurance depends on supportive relationships between stakeholders rather than punitive measures.

5.3 Scalability and sustainability of innovative approaches

To ensure scalability and sustainability of novel approaches like the decentralisation of seed production and quality assurance, piloted initiatives must be sustained, including (i) for capacity development; (ii) providing adequate resources (competent personnel, funding and the necessary technologies like electronic platforms); and (iii) most importantly, the presence of an entrenched policy, legal and institutional framework that is implemented on the ground. Interviewed officials within regulatory bodies in studied countries stressed the need to secure a strong political buy-in of the novel approaches, to ensure that there is dedicated funding, and staff at central and decentralised levels of government, to implement appropriate quality assurance systems.

In all countries, there are clear pathways for continued efforts to decentralise seed quality assurance for VPCs. For example, while Zambia remains behind in decentralising its seed inspection system, the government is implementing a full-scale decentralisation process and already some ministries, including the Ministry of Agriculture and Extension services and the Ministry of Education have decentralised offices at district level. These are opportunities through which the country can implement decentralised seed quality assurance mechanisms at the district level. As a starting point for countries like Zambia and or Malawi, the decentralisation of VPC seed production, seed inspection and certification can be done by focusing on clearly identified and known agroecological zones suitable for seed production of different crops. For example, in Zambia, the seed certification process is completely centralised, therefore all seed certification forms are submitted to the SCCI based in Lusaka. This needs to change so that seed production and inspection can take place in the three suitable agroecological zones (Interview, 12 August 2022).

For countries that have advanced in decentralising both seed production and quality control and assurance approaches, the full implementation of their policies, laws and required amendments is lacking; these also need improvement to cater for seed producers needs and time. For example, Kenya has quite elaborate seed laws but reforms are needed to ensure that the needs of informal seed producers, especially women, to produce quality seed of VPCs are taken on board to ensure social inclusion and equity (c.f. Sulle and Mudege, 2021). In Tanzania, where there are formally decentralised systems for seed inspection and certification, laws and policies now need to be

implemented to allow, for example, seed-producing companies to inspect their own seeds, while TOSCI focuses on its auditing or certification role.

Markets for both VPC seeds and produce is a great incentive for adoption of quality seeds and business growth and to encourage seed producers to seek and pay for inspection costs. Farmers, whether they are seed producers or crop producers, are motivated by the ability to sell more of their seed/produce. Seed producers need incentives to produce improved seed and crop producers need incentives to buy improved seed. Where a ready market exists for a crop such as sweetpotatoes, it incentivises the crop grower to use good quality seed that will lead to abundant quality crops, which the market is eager for. Seed producers will be incentivised to purchase starter seed of improved varieties to multiply and then sell to farmers because farmers will be more motivated to buy it.

The example of sweetpotato bread in Malawi is a good example: markets have been created by which sweetpotato farmers can sell their produce to bakeries; meanwhile, sweetpotato puree producers that sell to bakeries want consistent supplies of high quality roots of specific varieties in large amounts (Moyo *et al.*, 2022). Therefore, those growing sweetpotato are motivated to buy certified seed of processor-preferred varieties, so that they can produce better quality and more sweetpotatoes. The seed producers are, in turn, motivated to produce certified seed for the sweetpotato root farmers.

There are many lessons to be learned from countries that have advanced in decentralising novel approaches to VPC seed inspection and certification as part of their quality control and assurance. The key includes the ways in which project implementing agencies like IITA and CIP have worked hand-in-hand with government regulatory agencies to initiate systems that allow farmers' associations to be formed, which in turn can coordinate the requests for inspection and certification needs of VPC seed producers. This system helps in cutting costs and also allows decentralised systems of seed inspection to operate effectively as most of the seed inspectors reside close to where farmers are located – a key prerequisite for VPC planting materials.

5.4 Specific decentralisation requirements to address seed quality

The main requirements for decentralising VPC seed production and certification are

i. **Sufficient and qualified staff must work nearer to the communities they serve**, which may also mean they have to live closer to those communities, for example, extension workers and seed inspectors;
ii. **Financial resources are needed at local level** to ensure that local governments have the funds and other resources to undertake inspections, including, for example, transport cost and facilities and the regular maintenance of these;
iii. **Targeted training of seed inspectors is critical**. In many countries, seed standards for VPCs were designed based on the experiences of grain (maize) seeds, which have significant differences with VPCs. Therefore, seed inspectors need training for inspection of VPCs (i.e. varietal identification, crop specific pests and diseases).
iv. **Capacity development at different levels**. For example, train extension officers to undertake inspections and how to use relevant equipment, including any ICT devices; train seed producer associations on technical and governance/administrative aspects for ensuring equity, accountability and monitoring; and train seed producers to inspect their own seed and fields.
    a. **Capacity building can include training videos**, such as the two ICT-mediated videos in Uganda (mentioned above) that provide relevant information about potato seed multiplication and monitoring.
    b. Further, **capacity building must specifically ensure that women's capacity is built** so that they are not left out of the information loop, and they can also implement improvements in their own seed production activities;
v. **Establish and upscale seed producers' associations**. In countries where seed producer associations are in place, they have shown to be cost-effective in mobilising fellow seed producers, who need seed inspection and who can pay inspectors as a group instead of as individuals. This has in turn also driven the demand for inspection from the relevant authorities, as these inspection activities generate income for government agencies.

vi. **Help seed producers and farmers identify markets for both seed and produce**, to create a virtuous cycle, whereby ware producers buy improved seed because they have a market for their improved produce.

vii. **Implement or upscale e-certification platforms (e.g. SeedTracker™)** to reduce the burden and costs associated with manual and physical activities related to seed inspection and certification. Where ICT systems such as SeedTracker™ have not been implemented, roll these out in all countries, ensuring both that they are suitable for each country's specific needs, and that they are aligned with regional and international seed policy. Enable these platforms to be self-financing and are institutionalised into government structures. In countries like Nigeria and Tanzania where SeedTracker™ is in place, it is imperative that most of these tools are improved to address the current limitations.

viii. **Regular communication and dialogue at all levels,** including between farmers, seed producers and breeders about the preferred traits for improved varieties and any challenges farmers are facing, and between stakeholders to ensure that the stakeholders are aligned on the goals of seed quality assurance, how to ensure quality, and how to address problems.

ix. **Procedures and staff to monitor implementation**, identify sticking points and advise of adjustments needed.

x. **Awareness creation** on the benefits of decentralised systems, enabling tools and models for implementation to all stakeholders in the countries where this work was performed. Similar campaigns could also be rolled out to other countries, especially targeting policymakers to implement a fit-for-purpose system to enhance production of quality planting materials of VPCs in Africa.

6 CONCLUSIONS

This paper provides an inventory of novel approaches to seed quality assurance mechanisms with the aim of consolidating existing data and presents new data on decentralised quality assurance approaches in seven selected countries (Ethiopia, Uganda, Kenya, Nigeria, Tanzania, Malawi, Zambia) to make relevant information readily available for policy dialogue on appropriate and inclusive seed quality assurance systems. It assessed (i) the extent to which seed quality assurance systems have been decentralised, i.e. the extent to which third party accredited inspectors have been deployed; (ii) countries' use of e-certification platforms; (iii) the involvement of seed producer groups and cooperatives in seed QA; and (iv) any novel approaches to disease diagnostics or other relevant aspects of QA.

The paper finds that almost all studied countries have some sort of decentralised seed production systems in place, allowing large-scale companies, medium, semi-commercial companies and small holder farmers opportunities to produce both QDS and certified seeds. This innovative approach is suitable for VPC seeds like those of cassava, sweetpotato, potato, yams and bananas, all of which have bulky and/or perishable planting materials. To ensure efficient and effective inspection, most countries have also put in place devolved inspection mechanisms to ensure that the authorities and personnel involved in the inspection of VPC seeds are accessible to farmers associations and or individual farmers. More work is however needed to ensure that the devolved structures have sufficient resources, appropriate tools and implementation models they need to effectively do their inspection work.

As McEwan *et al.* (2020) show, decentralisation of seed production and assurance are critical for countries to achieve sustainable and healthy seed production. This is because the local seed production models assume that the highest quality of propagation material can be more rapidly and efficiently provided to farmers in distant areas when they are produced locally, especially in the case of VPCs that are bulky, perishable and difficult to transport across long distances. Specifically, a decentralised system that involves communities in seed production has been promoted as a way to involve farmers' groups or individual farmers "as private entrepreneurs who could provide key connections between the formal and informal sectors" (p. 678). Such farmers are expected to purchase genetically pure and properly inspected planting material, which they can be trained to multiply using clonal reproduction.

The evidence suggests that once farmers start producing and exchanging (selling or sharing) improved VPC, they continue to do so if they can access the relevant materials to continue production (Almekinders *et al.*, 2019). For example, DVMs, especially women, have been shown to sell/gift improved VPC seed or use it on their own farms (McEwan *et al.*, 2017).

Another important lesson from this inventory is that while it is important to stick to both legal provisions of seed laws (including those of novel approaches such as quality control and quality assurance mechanisms), rather simple, flexible and less bureaucratic systems are much more desirable for developing countries (Loch and Boyce, 2001)). These are also found to be the important pre-conditions for countries to not only pilot novel approaches such as decentralised seed production and quality control approaches but also to ensure the availability of planting materials. It is thus important for countries to mainstream and scale up sustainable quality assurance systems that work by establishing context-appropriate seed regulatory frameworks.

The paper concludes that for decentralised VPC production and devolved VPC seed inspection to be successful it is necessary for these processes to secure political buy-in so that states invest significant public resources to support regulatory agencies, decentralised offices, and farmers. The ongoing pilot efforts on decentralised systems, including the use of ICTs such as Seed Tracker™ for VPC seed production in Nigeria and Tanzania, serves as models for adopting in other countries. Governments need to make substantial public investments to ensure stakeholders can roll out and sustain the novel approaches studied in this report.

REFERENCES

Abebe, Z. (2020) 'Module: Seed quality control and assurance', in *Training manual on Seed Producer Cooperatives (SPCs)*. Wageningen, The Netherlands: Wageningen Centre for Development Innovation, Wageningen University. Available at: https://doi.org/10.18174/536875.

AGRA (2019) *Agricultural policy reforms in Tanzania: Reform on registration and access for new seed propagation, fertilizer industry regulations on registration and supply, contract farming and agricultural marketing*. Final report. Nairobi, Kenya: Alliance for a Green Revolution in Africa. Available at: https://agra.org/wp-content/uploads/2020/10/Agricultural-Policy-Reforms-in-Tanzania.pdf (Accessed: 3 July 2022).

Agricultural Transformation Agency (2016) *Seed system development strategy: Vision, systemic challenges, and prioritized interventions*. Available at: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC172079/ (Accessed: 19 June 2022).

Alemu, D., Yirga, C. and Bekele, A. (2018) 'Adoption of improved grain legume technologies in Ethiopia: Implications for research, extension and seed system', *Ethiopian Journal of Crop Science*, 6(3), pp. 425–501. Available at: https://www.researchgate.net/profile/Tesfaye-Disasa-Bitima/publication/330397645_Harnessing_Modern_Breeding_Tools_Techniques_and_Approaches_to_Improve_Yield_and_Quality_in_Legume_Crops/links/5c3e185d299bf12be3c9f709/Harnessing-Modern-Breeding-Tools-Techniques-and-Approaches-to-Improve-Yield-and-Quality-in-Legume-Crops.pdf (Accessed: 16 February 2023).

Alene, A. *et al.* (2013) 'Economic impacts of cassava research and extension in Malawi and Zambia', *Journal of Development and Agricultural Economics*, 5(11), pp. 457–469. Available at: https://doi.org/10.5897/JDAE2013.0496.

Almekinders, C.J.M. *et al.* (2019) 'Why interventions in the seed systems of roots, tubers and bananas crops do not reach their full potential', *Food Security*, 11(1), pp. 23–42. Available at: https://doi.org/10.1007/s12571-018-0874-4.

Andersen, K.F. *et al.* (2019) 'Modeling epidemics in seed systems and landscapes to guide management strategies: The case of sweet potato in Northern Uganda', *Phytopathology®*, 109(9), pp. 1519–1532. Available at: https://doi.org/10.1094/PHYTO-03-18-0072-R.

ASTA (2016) 'Guide to seed quality management practices'. American Seed Trade Association. Available at: https://www.betterseed.org/wp-content/uploads/Guide-to-Seed-Quality-Management2016.pdf (Accessed: 18 July 2022).

Awio, T. *et al.* (2019) 'Pioneering commercialization of certified cassava seed production: Impacts on sustainable cassava production, income and wealth creation in Uganda', *International Journal of Agricultural Technology*, 15(5), pp. 693–706. Available at: http://ijat-aatsea.com/pdf/v15_n5_2019_September/2_IJAT_15(5)_2019_Awio,%20T..pdf (Accessed: 17 August 2022).

Ayana, T.T. (2019) 'Demand and supply status of improved seed and factor governing it in Ethiopia', *Journal of Biology, Agriculture and Healthcare*, 9(3). Available at: https://core.ac.uk/download/pdf/234662769.pdf (Accessed: 18 June 2022).

Beavis, C.H.S. and Harty, R.L. (1997) 'Seed quality assurance', in D.S. Loch and J.E. Ferguson (eds) *Forage seed production: Tropical and subtropical species*. Oxon, UK: CABI Publishing, pp. 283–302.

Bentley, J.W. *et al.* (2017) *Cassava farmers' preferences for varieties and seed dissemination system in Nigeria: gender and regional perspectives*. Ibadan, Nigeria: International Institute of Tropical Agriculture. Available at: https://cgspace.cgiar.org/handle/10568/80554 (Accessed: 15 August 2022).

Bentley, J.W. *et al.* (2018) 'Understanding root, tuber, and banana seed systems and coordination breakdown: A multi-stakeholder framework', *Journal of Crop Improvement*, 32(5), pp. 599–621. Available at: https://doi.org/10.1080/15427528.2018.1476998.

Bentley, J.W. *et al.* (2020) 'Is there a space for medium-sized cassava seed growers in Nigeria?', *Journal of Crop Improvement*, 34(6), pp. 842–857. Available at: https://doi.org/10.1080/15427528.2020.1778149.

Bentley, J.W. *et al.* (2021) *Report on the first virtual seminar for the course on the RTB toolbox for working with root, tuber and banana seed systems*. Report. Lima, Peru: International Potato Center. Available at: https://cgspace.cgiar.org/handle/10568/114875 (Accessed: 17 August 2022).

Bishaw, Z., Niane, A.A. and Gan, Y. (2007) 'Quality seed production', in S.S. Yadav, D.L. McNeil, and P.C. Stevenson (eds) *Lentil: An ancient crop for modern times*. Dordrecht, The Netherlands: Springer International Publishing, pp. 349–383. Available at: https://doi.org/10.1007/978-1-4020-6313-8_21.

Brooks, S. (2014) 'Enabling adaptation? Lessons from the new "Green Revolution" in Malawi and Kenya', *Climatic Change*, 122(1), pp. 15–26. Available at: https://doi.org/10.1007/s10584-013-0992-0.

CIP (2021) *Development of seed potato certification protocol for Uganda*. Outcome brief 1. Lima, Peru: International Potato Center. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/113052/outcome.pdf?sequence=1 (Accessed: 2 August 2022).

CIP (2022) *Exploiting fully the potential of potato to increase food security in Uganda*. Lima, Peru: International Potato Center and Consultative Group on International Agricultural Research. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/116229/0147.pdf?sequence=1&isAllowed=y (Accessed: 11 August 2022).

Damtew, E. *et al.* (2018) 'Diagnosis of management of bacterial wilt and late blight in potato in Ethiopia: A systems thinking perspective', *NJAS - Wageningen Journal of Life Sciences*, 86–87, pp. 12–24. Available at: https://doi.org/10.1016/j.njas.2018.03.003.

Federal Ministry of Agriculture and Rural Development (2015) *National Seed Policy*.

Gatto, M. *et al.* (2021) 'Policy options for advancing seed systems for vegetatively propagated crops in Vietnam', *Journal of Crop Improvement*, 35(6), pp. 763–789. Available at: https://doi.org/10.1080/15427528.2021.1881011.

Gildemacher, P. *et al.* (2016) 'Common challenges to promote seed entrepreneurship', March.

Gildemacher, P. *et al.* (2017) *Effective seed quality assurance*. Synthesis paper. Wageningen, The Netherlands: ISSD Africa.

Gildemacher, P.R. *et al.* (2013) 'Common challenges to promote seed entrepreneurship'. *ISSD Africa TWG 1*, Nairobi, Kenya, 24 March.

Grabe, D.F. (2021) 'Quality control in seed production'. Scholars Junction, Mississippi State University. Available at: https://scholarsjunction.msstate.edu/cgi/viewcontent.cgi?article=1143&context=seedtechpapers (Accessed: 18 July 2022).

Gurmu, F. (2019) 'Sweetpotato research and development in Ethiopia: A comprehensive review', *Journal of Agricultural and Crop Research*, 7(7), pp. 106–118. Available at: http://www.sciencewebpublishing.net/jacr/archive/2019/July/Abstract/Gurmu.htm (Accessed: 9 August 2022).

de Haan, N. (2021) 'Exploring the banana and cassava seed systems: A case study of Luwero district in Central Uganda'. *RTB Seed System Toolbox Course*, 25 October. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/116335/03.pdf?sequence=1 (Accessed: 10 October 2022).

Hassena, M., Broek, J. van den and Borman, G. (2020) *Institutional mapping and needs assessment of Ethiopia's public seed sector services*. Final report to RVO WCDI-20-101. Wageningen, The Netherlands: Wageningen Centre for Development Innovation, Wageningen University, p. Available at: https://library.wur.nl/WebQuery/wurpubs/562068 (Accessed: 17 August 2022).

Henry, M.-M., Kibwika, P. and Nampala, P. (2022) 'The Interplay between informal and formal bylaws in supporting sustainable crop intensification in the Uganda potato production system', *Sustainable Agriculture Research*, 11(2), pp. 1–13. Available at: https://doi.org/10.5539/sar.v11n2p1.

Hirpa, A. *et al.* (2010) 'Analysis of seed potato systems in Ethiopia', *American Journal of Potato Research*, 87(6), pp. 537–552. Available at: https://doi.org/10.1007/s12230-010-9164-1.

Hummel, M. *et al.* (2018) 'Sensory and cultural acceptability tradeoffs with nutritional content of biofortified orange-fleshed sweetpotato varieties among households with children in Malawi', *PLOS ONE*, 13(10), p. e0204754. Available at: https://doi.org/10.1371/journal.pone.0204754.

Kanyamuka, J.S., Dzanja, J.K. and Nankhuni, F.J. (2018) *Analysis of the value chains for root and tuber crops in Malawi: The case of cassava*. Policy Research Brief 65. East Lansing, Michigan: Department of Agricultural, Food, and Resource Economics, Michigan State University. Available at: https://doi.org/10.22004/ag.econ.275675.

Kathabwalika, D.M. *et al.* (2013) 'Plant growth and yield stability of orange fleshed sweet potato (Ipomoea batatas) genotypes in three agro-ecological zones of Malawi', *International Research Journal of Agriculture and Soil Science*, 3(11), pp. 383–392. Available at: https://www.interesjournals.org/articles/plant-growth-and-yield-stability-of-orange-fleshed-sweet-potato-ipomoea-batatas-genotypes-in-three-agroecological-zones-.pdf (Accessed: 15 February 2023).

Kilwinger, F., Rietveld, A.M. and Almekinders, C.J.M. (2019) *A comparative study on banana seed systems in Mbarara district, western Uganda and Mukono district, central Uganda*. Working Paper. Lima, Peru: International Potato Center. Available at: https://doi.org/10.4160/23096586RTBWP20194.

Kilwinger, F.B.M. *et al.* (2019) 'Culturally embedded practices of managing banana diversity and planting material in central Uganda', *Journal of Crop Improvement*, 33(4), pp. 456–477. Available at: https://doi.org/10.1080/15427528.2019.1610822.

Kuhlmann, K. and Dey, B. (2021) 'Using regulatory flexibility to address market informality in seed systems: A global study', *Agronomy*, 11(2), p. 377. Available at: https://doi.org/10.3390/agronomy11020377.

Kuhlmann, K., Zhou, Y. and Keating, S. (2019) *Seed policy harmonization in COMESA and SADC: The case of Zambia*. Working Paper. Washington, DC, USA: New Markets Lab, Sygenta Foundation. Available at: https://www.syngentafoundation.org/sites/g/files/zhg576/f/zambia_case_study_final_edit_8_march_2019_clean.pdf (Accessed: 5 July 2022).

Kumar, P. *et al.* (2020) 'Seed yam quality assurance'. *4th YIIFSWA-II Annual Review and Planning Meeting*, Abuja, Nigeria: YIIFSWA-II, February. Available at: https://cgspace.cgiar.org/bitstream/handle/10568/107937/SEED%20YAM%20QUALITY.pdf?sequence=1 (Accessed: 17 August 2022).

Kumwenda, W. (2018) 'Experience with gender integration in SUSTAIN Malawi'. *Effects of commercialization of sweetpotato on gender relations and wellbeing among smallholder farmers: Technical workshop to review study findings and develop recommendations for improved programming*, Nairobi, Kenya, 8 November. Available at: https://doi.org/10.4160/9789290605096.

Loch, D. and Boyce, K. (2001) 'Meeting the changing need for herbage seed Quality Assurance in the 21st Century', in *International Grassland Congress Proceedings*. *XIX International Grassland Congress*, São Paulo, Brazil: International Grassland Congress, pp. 1–21. Available at: https://uknowledge.uky.edu/igc/19/3/10 (Accessed: 11 August 2022).

Longley, C. *et al.* (2021) *Uganda seed sector profile*. Report. Baltimore, Maryland: USAID Feed the Future. Available at: https://cgspace.cgiar.org/handle/10568/119639 (Accessed: 10 October 2022).

Louwaars, N.P. and de Boef, W.S. (2012) 'Integrated seed sector development in Africa: A conceptual framework for creating coherence between practices, programs, and policies', *Journal of Crop Improvement*, 26(1), pp. 39–59. Available at: https://doi.org/10.1080/15427528.2011.611277.

Louwaars, N.P., de Boef, W.S. and Edeme, J. (2013) 'Integrated seed sector development in Africa: A basis for seed policy and law', *Journal of Crop Improvement*, 27(2), pp. 186–214. Available at: https://doi.org/10.1080/15427528.2012.751472.

Mabaya, E. *et al.* (2017) *Ethiopia brief 2017: The African Seed Access Index*. Index. Abuja, Nigeria: The African Seed Access Index. Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Mabaya, E. *et al.* (2019) *Zambia Brief 2017*. Brief. Nairobi, Kenya: The African Seed Access Index. Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Mabaya, E., Kachule, R., *et al.* (2021) *Malawi country report 2020*. Country index. The African Seed Access Index (TASAI). Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Mabaya, E., Ajayi, S.A., *et al.* (2021) *Nigeria Country Report 2020*. Index. Abuja, Nigeria: The African Seed Access Index. Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Mabaya, E., Mizambwa, F., *et al.* (2021) *Tanzania Country Report 2021*. Index. The African Seed Access Index. Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Mabaya, E., Waithaka, M., *et al.* (2021) *Uganda Country Report 2020*. Ithaca, New York and Nairobi, Kenya: The African Seed Access Index. Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Madu, T. *et al.* (2022) 'Differentials in the Cassava Seed System among Entrepreneurs in Southern Nigeria: A Gender Situation Analyses', *Agricultural Science*, 4(1), p. p9. Available at: https://doi.org/10.30560/as.v4n1p9.

Maroya, N. *et al.* (2022) 'Transforming yam seed systems in West Africa', in G. Thiele et al. (eds) *Root, tuber and banana food system innovations: Value creation for inclusive outcomes*. Champaign, Illinois: Springer International Publishing, pp. 145–172. Available at: https://library.oapen.org/bitstream/handle/20.500.12657/54016/978-3-030-92022-7.pdf?sequence=1#page=174 (Accessed: 17 August 2022).

Mastenbroek, A., Otim, G. and Ntare, B.R. (2021) 'Institutionalizing Quality Declared Seed in Uganda', *Agronomy*, 11(8), p. 1475. Available at: https://doi.org/10.3390/agronomy11081475.

Mausch, K. *et al.* (2021) 'Putting diverse farming households' preferences and needs at the centre of seed system development', *Outlook on Agriculture*, 50(4), pp. 356–365. Available at: https://doi.org/10.1177/00307270211054111.

Mbewe, W. *et al.* (2021) 'Incidence and distribution of Sweetpotato viruses and their implication on sweetpotato seed system in Malawi', *Journal of Plant Pathology*, 103(3), pp. 961–968. Available at: https://doi.org/10.1007/s42161-021-00830-4.

McEwan, M. (2014) *Institutional arrangements for sustainable sweetpotato seed systems*. Terminal Report 1001. Seattle, Washington: Bill and Melinda Gates Foundation, p. 1001. Available at: https://gatesopenresearch.org/documents/3-1001 (Accessed: 5 August 2022).

McEwan, M. (2016) *Sweetpotato seed systems in sub-saharan Africa: A literature review to contribute to the preparation of conceptual frameworks to guide practical interventions for root, tuber and banana seed systems*. Working Paper. Lima, Peru: International Potato Center. Available at: https://doi.org/10.4160/23096586RTBWP20164.

McEwan, M.A. *et al.* (2017) 'Specialised sweetpotato vine multiplication in Lake Zone, Tanzania: What "sticks" and what changes?', *Open Agriculture*, 2(1), pp. 64–69. Available at: https://doi.org/10.1515/opag-2017-0007.

McEwan, M.A. *et al.* (2020) 'Decentralised sweetpotato (Ipomoea batatas) vine multiplication in Lake Zone, Tanzania: Five years later', *Open Agriculture*, 5(1), pp. 677–689. Available at: https://doi.org/10.1515/opag-2020-0064.

McEwan, M.A. *et al.* (2021) *Exploring the regulatory space for improving availability, access and quality of vegetatively propagated crop seed: potato in Kenya*. Working Paper. Lima, Peru: CGIAR Research Program on Roots, Tubers and Bananas. Available at: 10.4160/23096586RTBWP20211 (Accessed: 5 March 2022).

Mignouna, D.B. *et al.* (2013) 'Economic analysis of yam seed tuber systems in Nigeria', *Journal of Root Crops*, 39(2), pp. 221–229. Available at: http://journal.isrc.in/index.php/jrc/article/view/138 (Accessed: 15 August 2022).

Ministry of Agriculture (2020) *Transforming the Ethiopian seed sector: Issues and strategies*. Unpublished. Available at: http://rgdoi.net/10.13140/RG.2.2.28343.75680 (Accessed: 19 June 2022).

Ministry of Agriculture, Animal Industry and Fisheries (2018a) *Uganda National Seed Policy*.

Ministry of Agriculture, Animal Industry and Fisheries (2018b) *Uganda National Seed Strategy*.

Ministry of Agriculture, Irrigation and Water Development (2018) *Malawi National Seed Policy*. Available at: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC180417/ (Accessed: 21 April 2022).

Moyo, C.C. *et al.* (2004) 'Cassava and sweetpotato yield assessment in Malawi', *African Crop Science Journal*, 12(3), pp. 295–303. Available at: https://doi.org/10.4314/acsj.v12i3.27891.

Moyo, M. *et al.* (2022) 'Orange-fleshed sweetpotato puree: A breakthrough product for the bakery sector in Africa', in G. Thiele et al. (eds) *Root, tuber and banana food system innovations: Value creation for inclusive outcomes*. Champaign, Illinois: Springer International Publishing, pp. 145–172. Available at: https://library.oapen.org/bitstream/handle/20.500.12657/54016/978-3-030-92022-7.pdf?sequence=1#page=174 (Accessed: 17 August 2022).

Mudege, N.N., Kapalasa, E., *et al.* (2015) 'Gender norms and the marketing of seeds and ware potatoes in Malawi.', *Journal of Gender, Agriculture and Food Security*, 1(2), pp. 18–41. Available at: https://cgspace.cgiar.org/handle/10568/68547 (Accessed: 16 August 2022).

Mudege, N.N., Nyekanyeka, T., *et al.* (2015) 'Understanding collective action and women's empowerment in potato farmer groups in Ntcheu and Dedza in Malawi', *Journal of Rural Studies*, 42, pp. 91–101. Available at: https://doi.org/10.1016/j.jrurstud.2015.09.002.

Mudege, N.N. *et al.* (2018) 'Scaling up of sweetpotato vine multiplication technologies in Phalombe and Chikwawa districts in Malawi: A gender analysis', *NJAS - Wageningen Journal of Life Sciences*, 85, pp. 1–9. Available at: https://doi.org/10.1016/j.njas.2018.05.003.

Mudege, N.N. and Demo, P. (2016) 'Seed potato in Malawi: Not enough to go around', in J. Andrade-Piedra et al. (eds) *Case Studies of Roots, Tubers and Bananas Seed Systems*. Lima, Peru: International Potato Center (CIP) (RTB Working Paper), pp. 146–163.

Mudege, N.N., Kebaara, K. and Mukewa, E. (2019) *Effects of commercialization of sweetpotato on gender relations and wellbeing among smallholder farmers: Technical workshop to review study findings and develop recommendations for improved programming*. Workshop report. Nairobi, Kenya: International Potato Center. Available at: https://doi.org/10.4160/9789290605096.

Mwakanyamale, D.F. *et al.* (2021) *Gender barriers and success factors that shape women's involvement in and benefits from cassava seed production businesses in Tanzania*. Study report. Ibadan, Nigeria: International Institute of Tropical Agriculture. Available at: https://biblio1.iita.org/bitstream/handle/20.500.12478/7293/U21RepNwakanyamaleGenderNothomNodev.pdf?sequence=1 (Accessed: 10 October 2022).

Mwangi, C.W. *et al.* (2020) 'Seed security for vegetatively propagated orphaned crops and its implication for household food security in rural Kenya: A case of sweet potato (Ipomea batatas)', *Journal of Agriculture and Food Research*, 2, p. 1=8. Available at: https://doi.org/10.1016/j.jafr.2020.100087.

Mwangi, C.W. *et al.* (2022) 'Comparing farmers' willingness to pay with costs of clean sweet potato seed multiplication in Kenya', *Food Security* [Preprint]. Available at: https://doi.org/10.1007/s12571-022-01293-w.

Nakabonge, G., Samukoya, C. and Baguma, Y. (2018) 'Local varieties of cassava: Conservation, cultivation and use in Uganda', *Environment, Development and Sustainability*, 20(6), pp. 2427–2445. Available at: https://doi.org/10.1007/s10668-017-9997-6.

Namanda, S. *et al.* (2021) *Assessment of Seed Producer Associations in Uganda*. Report. Lima, Peru: International Potato Center. Available at: https://doi.org/10.4160/9789290606147.

Namanda, S., Gibson, R. and Sindi, K. (2011) 'Sweetpotato seed systems in Uganda, Tanzania, and Rwanda', *Journal of Sustainable Agriculture*, 35(8), pp. 870–884. Available at: https://doi.org/10.1080/10440046.2011.590572.

National Agricultural Seeds Council and Seed Entrepreneurs Association of Nigeria (2020) *National seed road map for Nigeria*. Wageningen, The Netherlands: Wageningen Centre for Development Innovation. Available at: https://doi.org/10.18174/517834 (Accessed: 2 July 2022).

Okello, J. *et al.* (2018) *Sweetpotato for Profit and Health Initiative: Status of sweetpotato in Sub-Saharan Africa*. Project report. Lima, Peru: International Potato Center (CIP). Available at: https://www.sweetpotatoknowledge.org/wp-content/uploads/2018/12/2018-SWEETPOTATO-IN-SSA-STATUS-REPORT-_PDF.pdf (Accessed: 17 August 2022).

Okello, J. *et al.* (2019) 'Motivations and mental models associated with smallholder farmers' adoption of improved agricultural technology: Evidence from use of quality seed potato in Kenya', *The European Journal of Development Research*, 31(2), pp. 271–292. Available at: https://doi.org/10.1057/s41287-018-0152-5.

Okello, J.J. *et al.* (2015) 'Effect of technology awareness and access on the conservation of clean planting materials of vegetatively produced crops: The case of sweetpotato', *Agroecology and Sustainable Food Systems*, 39(9), pp. 955–977. Available at: https://doi.org/10.1080/21683565.2015.1053586.

Olayide, O.E. *et al.* (2021) 'Cassava seedpreneurship, determinants of varietal adoption, profitability, and women empowerment in Nigeria', *Resources, Environment and Sustainability*, 6, pp. 1–5. Available at: https://doi.org/10.1016/j.resenv.2021.100041.

Ong'ayo, M.J. *et al.* (2020) 'Role of networking capability, socio-economic and institutional characteristics on adoption tendencies of clean seed potato agri-enterprises in central Rift Valley, Kenya', *African Crop Science Journal*, 28(s1), pp. 131–144. Available at: https://doi.org/10.4314/acsj.v28is1.10S.

Ong'ayo, M.J. (2021) *Networking capability, adoption tendencies and commercialization: Case of decentralized clean seed potato multiplication agri-enterprises in Nakuru County, Kenya*. MSc (Agri-Enterprise Development). Department of Agricultural Economics and Agribusiness Management, Egerton University. Available at: http://41.89.96.81:8080/xmlui/handle/123456789/2768 (Accessed: 14 August 2022).

Osei-Adu, J. *et al.* (2022) 'Profitability of positive selection technique for seed yam production in Ghana and Nigeria', *Cogent Economics & Finance*. Edited by R. Read, 10(1), p. 2034281. Available at: https://doi.org/10.1080/23322039.2022.2034281.

Ouma, T. *et al.* (2019) 'Open data kit (ODK) in crop farming: Mobile data collection for seed yam tracking in Ibadan, Nigeria', *Journal of Crop Improvement*, 33(5), pp. 605–619. Available at: https://doi.org/10.1080/15427528.2019.1643812.

Parker, M. *et al.* (n.d.) 'Visual inspection to manage bacterial wilt in Sub-Saharan Africa: Improving seed quality and impacting smallholder farmers'.

Pircher, T. *et al.* (2019) *Characterizing Nigeria's cassava seed system and the use of planting material in three farming communities*. Working Paper. Lima, Peru: International Potato Center. Available at: https://doi.org/10.4160/23096586RTBWP20191.

Pircher, T. and Almekinders, C.J.M. (2021) 'Making sense of farmers' demand for seed of root, tuber and banana crops: A systematic review of methods', *Food Security*, 13(5), pp. 1285–1301. Available at: https://doi.org/10.1007/s12571-021-01157-9.

Rondinelli, D.A., Nellis, J.R. and Cheema, G.S. (1983) *Decentralization in developing countries: A review of recent experiences*. Working Paper 581. Washington, DC, USA: World Bank, pp. 13–28. Available at: https://documents1.worldbank.org/curated/en/868391468740679709/pdf/multi0page.pdf (Accessed: 5 August 2022).

Schulz, S. *et al.* (2013) 'Sustainable seed potato production in Ethiopia: From farm-saved to Quality Declared Seed', in G. Waldegiorgis, S. Schulz, and B. Berihun (eds) *Seed potato tuber production and dissemination experiences, challenges and prospects*. *National Workshop on Seed Potato Tuber Production and Dissemination, 12-14 March 2012, Bahir Dar, Ethiopia*, Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research, Amhara Regional Agricultural Research Institute, pp. 60–71.

Singh, D. *et al.* (2019) 'Farmer participatory seed production: extending the Indian experience to Africa', in. *6th African Conference of Agricultural Economists*, Abuja, Nigeria: African Association of Agricultural Economists. Available at:

https://ageconsearch.umn.edu/record/295948/files/478.%20Seed%20in%20India%20and%20Africa.pdf (Accessed: 16 August 2022).

Sperling, L., Boettiger, S. and Barker, I. (2013) *Integrating seed systems*. Brief 3. Basel, Switzerland: Ag Partner Xchange. Available at: https://seedsystem.org/wp-content/uploads/2014/03/Integrating-Seed-Systems-.pdf (Accessed: 15 August 2022).

Spielman, D. (2020) *Seed policies and regulatory reforms*. Pretoria, South Africa: Regional Strategic Analysis and Knowledge Support System, pp. 27–32.

Spielman, D.J. *et al.* (2021) *Regulatory options to improve seed systems for vegetatively propagated crops in developing countries*. 0 edn. Washington, DC: International Food Policy Research Institute. Available at: https://doi.org/10.2499/p15738coll2.134441.

Spielman, D.J. and McEwan, M.A. (2020) 'Framing policy options for seed market development for low- middle-income countries'. *Participatory plant breeding and resilient seed system development: Options for stakeholder engagement and benefit sharing*, Wageningen, The Netherlands, 30 December.

Stuart, E. *et al.* (2021) 'Yam seed system characteristics in Nigeria: Local practices, preferences, and the implications for seed system interventions', *Outlook on Agriculture*, 50(4), pp. 455–467. Available at: https://doi.org/10.1177/00307270211058209.

Sulle, E. and Mudege, N.N. (2021) *Integrating gender into Kenya's evolving seed policies and regulations for roots and tubers*. Working Paper 2021–3. Lima, Peru: International Potato Center (CIP). Available at: https://cgspace.cgiar.org/bitstream/handle/10568/118033/0188_Integrating_Gender.pdf?sequence=1&isAllowed=y (Accessed: 20 August 2022).

Szyniszewska, A.M. *et al.* (2021) 'Smallholder Cassava Planting Material Movement and Grower Behavior in Zambia: Implications for the Management of Cassava Virus Diseases', *Phytopathology*®, 111(11), pp. 1952–1962. Available at: https://doi.org/10.1094/PHYTO-06-20-0215-R.

Tadesse, Y. *et al.* (2020) 'Collective production and marketing of quality potato seed: Experiences from two cooperatives in Chencha, Ethiopia', *Forum for Development Studies*, 47(1), pp. 139–156. Available at: https://doi.org/10.1080/08039410.2019.1635523.

Tafesse, S. *et al.* (2020) 'Analysis of a monitoring system for bacterial wilt management by seed potato cooperatives in Ethiopia: Challenges and future directions', *Sustainability*, 12(9), pp. 1–20. Available at: https://econpapers.repec.org/article/gamjsusta/v_3a12_3ay_3a2020_3ai_3a9_3ap_3a3580-_3ad_3a351460.htm (Accessed: 10 August 2022).

Tech Gist Africa (2019) 'Nigerian agricultural sector introduces smart seed labeling technology to eliminate low-quality seeds', *Techgist Africa*, 6 May. Available at: https://www.techgistafrica.com/news/nigerian-agricultural-sector-introduces-smart-seed-labeling-technology-to-eliminate-low-quality-seeds/ (Accessed: 19 August 2022).

The East African (2009) 'Diseases threaten to wipe out bananas in sub-Saharan Africa', *The East African*. Online, 29 August. Available at: https://www.theeastafrican.co.ke/tea/news/east-africa/diseases-threaten-to-wipe-out-bananas-in-sub-saharan-africa--1295964 (Accessed: 16 February 2023).

Tione, G. *et al.* (2018) 'Improved potato variety analysis in Malawi: An evaluation of farmers seed demand', *Canadian Journal of Agriculture and Crops*, 3(2), pp. 81–87. Available at: https://econpapers.repec.org/article/onlcjoaac/v_3a3_3ay_3a2018_3ai_3a2_3ap_3a81-87_3aid_3a392.htm (Accessed: 16 August 2022).

United Republic of Tanzania (2020) *The Seeds (Control of Quality Declared Seeds) Regulations, 2020 (subsidiary legislation)*, *Cap*.

Vandevelde, S., Van Campenhout, B. and Walukano, W. (2021) 'Accounting for spillovers in assessing the effectiveness of video messages to improve potato seed quality: Evidence from Uganda', *The Journal of Agricultural Education and Extension*, 27(4), pp. 503–534. Available at: https://doi.org/10.1080/1389224X.2021.1880454.

van Vugt, D. and Franke, A.C. (2018) 'Exploring the yield gap of orange-fleshed sweet potato varieties on smallholder farmers' fields in Malawi', *Field Crops Research*, 221, pp. 245–256. Available at: https://doi.org/10.1016/j.fcr.2017.11.028.

Waithaka, M. *et al.* (2019) *Kenya brief 2018: The African Seed Access Index*. The African Seed Access Index (TASAI). Available at: https://www.tasai.org/en/products/country-reports/ (Accessed: 16 February 2023).

Waliyar, F., Hoisington, D. and Rhoads, J. (2021) *Malawi groundnut seed sector*. Case Study Report. Athens, Georgia: Peanut Innovation Lab, College of Agriculture and Environmental Sciences, University of Georgia.

Wokorach, G., Edema, H. and Echodu, R. (2018) 'Sweetpotato seed exchange systems and knowledge on sweetpotato viral diseases among local farmers in Acholi Sub Region-Northern Uganda', *African Journal of Agricultural Research*, 13(45), p. 10.5897/AJAR2018.13384. Available at: https://doi.org/10.5897/AJAR2018.13384.

Wossen, T. *et al.* (2020) *The cassava seed system in Nigeria: Opportunities and challenges for policy and regulatory reform*. Working Paper. Lima, Peru: International Potato Center. Available at: https://doi.org/10.4160/23096586RTBWP20202.

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