Chapter 8. Introducing improved vegetable varieties in a development context: lessons for the introduction of hybrid true potato seed

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Abstract

Hybrid true potato seed (HTPS) technology has potential to strengthen the smallholder potato sector in Sub-Saharan Africa. For its successful introduction, stakeholders will need to realise promises of the innovation and overcome barriers to adoption. Both promises and barriers can be analysed looking at the seed, farm, and market system. Efforts of two pairs of Dutch vegetable seed companies, East-West Seed and Rijk Zwaan introducing improved tomato varieties in Tanzania, and De Groot & Slot and Bejo introducing true-seed shallots in Indonesia, offer lessons learned when developing a strategy for HTPS in Sub-Saharan Africa. The SEVIA project in Tanzania (2013-2020) demonstrated that main barriers to adoption of tomato varieties were posed by the seed and farm system. The investment in seed of improved crop varieties was worthwhile, only if tomato farmers improved their full-field production practices, and prior nursery care. There were no barriers regarding the market system, but there were also no incentives for adoption: tomato is mostly a commodity in Tanzania and there is no diversified market. The 'True Seed Shallot demonstration project' in Indonesia (2018-2020) sought to introduce true shallot seed (TSS) varieties requiring a transformation of the seed, farm, and market system. The companies decided to promote TSS outside traditional shallot production areas where the potential positive impact of their innovation was larger. Vegetable farmers, familiar with seedlings while unfamiliar with shallots, were trained in shallot production from seed. Adoption of HTPS will, like improved shallot and tomato varieties, require transformations of the seed, farm, and market systems. The two cases show that investments in seed system development are essential. Widespread outreach efforts are needed to demonstrate the promise of an innovation. Moreover, capacity building is then required to enable farmers to realise the potential of an improved variety themselves. Without additional skills, adoption of an innovation is often not economical. In summary, farmers need to be familiarised with the technology and recognise its profitability. Subsequently,

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HTPS technology can be mainstreamed in the seed, farm, and market system minimising disruption and maximising innovation.

Keywords: farm system, market system, seed system, innovation

8.1 Introduction

'Dutch' vegetable seed companies have extensive experience working in developing countries introducing and marketing improved varieties. The aim of this chapter is to draw lessons from these experiences that may predict and overcome challenges of introducing hybrid true potato seed (HTPS) varieties in Sub-Saharan Africa. The structure of the chapter is based on a distinction between the seed, farm, and market system. Firstly, the concept of 'system transformation' is introduced, after which the three different systems are defined and linked to the introduction of improved crop varieties. Subsequently, two case studies regarding tomato in Tanzania and shallot in Indonesia will be analysed looking at the promise of these innovations, barriers to adoption and interventions implemented to overcome these barriers. The case studies are based on two interviews with Flip van Koesveld of Wageningen Plant Research and Rob Bekker of De Groot & Slot. A comparative analysis follows in which lessons learned from the two case studies are applied to the case of HTPS in East Africa. HTPS represents a technological breakthrough in potato breeding (Lindhout *et al.*, 2011; Zhang *et al.*, 2021). Still, the real-world adoption of the HTPS technology may be hampered by systemic obstacles comparable to those faced by seed companies in the past with other crops. The chapter analyses the benefits of adoption of the improved varieties and tries to pre-empt the barriers to adoption that will have to be overcome for successful adoption. Insights from the two cases are used to discuss the probable benefits and help predict barriers for adoption of HTPS.

8.2 System transformation

A distinction can be made between the adoption of a new variety and adoption of a new technology. With the introduction of a new variety, seed companies seek to convince farmers of the added benefit offered by their product. They may organise demonstrations or give away free seed samples to show farmers how the variety performs in a field like his or her own field. Introduction of a new variety can be challenging. Research and experience have shown that even though benefits of an improved variety are demonstrated, farmers may still refrain from adoption (Almekinders *et al.*, 2019; Hoogendoorn *et al.*, 2018; Kilwinger *et al.*, 2022). Contextual factors always need to be considered providing insight into a farmer's livelihood and constraints. Moreover, habits, culture, and traditions are also strong forces, which may pose a barrier to change or prevent adoption of an innovation (Almekinders *et al.*, 2019).

Introduction of a new (breeding) technology is (much) more challenging. Successful introduction of a technology-based innovation hardly ever goes automatically: a system transformation is required to accommodate the innovation. Smits (2002) distinguishes between software, hardware and 'org-ware' required for successful introduction of an innovation, to emphasise that a technology cannot stand on its own but needs to be accompanied by changes in knowledge of and organisation between actors. Vegetable seed companies have been involved in capacity building programmes for many years to build their own market. East-West Seed (EWS) was one of the first to focus on training enabling farmers to realise the potential of quality seed and improved varieties. Without additional skills and knowledge, they could not benefit from a technology and, hence, would not adopt it. Similarly, the introduction of HTPS goes beyond the decision of a farmer whether to adopt a new variety. The success of the introduction of HTPS will depend on the entire systemic context in which the technology is introduced.

A new system will compete with the established system, which holds the simple but crucial advantage of predictability. Farmers know the risks and returns from their own experience. Farming practices have developed based on experiences of farmers themselves and those of their neighbours. Farmers, and in particular smallholders, are cautious in making changes to their practices, and rightly so, as change equals risk (Pannell and Zilberman, 2020). They are typically cash-short and need to prioritise in their investments keeping risks low. In terms of returns, new varieties can have a positive impact in terms of yields, marketability, or ease of production. However, quite often there are also negative impacts or (perceived) higher risks associated with variety adoption. There is an inevitable learning period during which farmers must gather new knowledge and gain skills (Kuehne *et al.*, 2017). The length of this learning period will depend on the learnability of the technology itself as well as the capacity of the targeted population to learn. Due to this period, benefits of adoption will not materialise immediately.

We distinguish between three systems of which transformation may be required for the adoption of a new variety: the seed, farm, and market system. These systems are interlinked. The seed system focuses on the starting material used by a farmer, the farm system focuses on the livelihood structure of the farmer and the market system focuses on sales realised by the farmer. The type of variety grown can determine whether farmers sell their produce to a supermarket or an intermediary or on a local market. Prices offered by exporters, supermarkets or local markets can determine how much a farmer is able to invest in seed and inputs. Moreover, when a farmer invests in expensive seeds and inputs, a farmer will seek to earn a return on this investment either selling more kilos or obtaining a better price per kilo sold. Besides money, improved quantity and/or quality of the harvested crops will require the application of cultivation techniques representing an investment in terms of time and effort.

8.3 Seed system

Seed systems represent the set of activities affecting access and use of seeds including breeding, multiplication, seed management and distribution (Tripp, 1997). Some authors refer to seed systems as the set of market and non-market institutions governing these activities (Lipper *et al.*, 2010). The availability, quantity, quality, and price of seed are key factors which influence the choice made by farmers (Louwaars *et al.*, 2013). Physiological quality (germination/sprouting and vigour), sanitary quality (no seed-borne diseases or pests), analytical quality (high number of good seeds in a unit) and genetic quality (improved variety and varietal purity) can be hard to manage for seed producers and to verify for users (Almekinders and Louwaars, 1999). While it is relatively easy to produce and select seeds for some crops, the chances of disease transmission or degeneration are high for others (Almekinders and Louwaars, 1999). In addition to improved seed quality and availability of quality seed, there is the question of seed diversity, which enhances farmer choice and enables farmers to choose a preferred type of variety or seed (Nabuuma *et al.*, 2020).

Traditionally, a distinction is made between informal and formal seed systems (Louwaars and De Boef, 2012; Louwaars *et al.*, 2013). In informal seed systems, farmers select, produce, and distribute seeds themselves. These seed systems have also been referred to as farmer-managed, traditional, and local seed systems. Farmers use their own saved seed, exchange seed with neighbours or trade seed on local markets. There is no specialised chain with fixed standards for seed quality. Quality is managed through social structures based on reputation rather than regulation. In formal seed systems, seed reaches farmers through a specialised, regulated chain. Improved plant varieties are generated by professional plant breeders and seed production is done by professional seed producers. Seed is sold via market channels and farmers have access through purchases. Seed quality is managed through government regulation, official certification schemes and company standards. Also, branded packaging of seed companies provides reassurance. In Sub-Saharan Africa, it is estimated that around 80% of seed used is produced by the informal system (Louwaars *et al.*, 2013; World Bank, 2007). For potato, this number is much higher and can reach around 95-98% (Gildemacher *et al.*, 2009a).

Louwaars *et al.* (2013) distinguish between four types of seed systems: the farm-saved, locally sourced, nationally sourced, and globally sourced seed system. A generic overview of the four systems and their characteristics is provided below in Table 8.1 based on Louwaars *et al.* (2013). In these systems, there is an increasing distance between the farmer and the seed producer. Also, there is an increasing level of formalisation and standardisation.

Table 8.1 illustrates that switching immediately from a local to a hybrid variety represents a major shift. The system, variety type, seed producers and marketing mechanism are all different. Moreover, the cost of seed will be higher posing a financial barrier and cultivation practices

Table 8.1. Overview of four generic types of seed system.

	Informal		**Formal**	
Seed system	**Farm-saved**	**Locally sourced**	**Nationally sourced**	**Globally sourced**
Variety type	Local variety	Local variety; improved OPVs[1]	Improved varieties; OPVs and hybrids	Improved varieties; mostly hybrids
Seed and seed producers	Local seed produced by farmers	Local seed produced by both specialised farmers and farmers	Certified seed produced by professional seed producers	Certified seed produced by professional seed producers
Seed marketing mechanism	Farm-saved, exchange and trading	Local markets, seed producers and companies	Agro-dealers, local markets, and seed companies	Agro-dealers, seed companies and input suppliers

[1] OPV = open-pollinated variety.

may differ posing a barrier related to knowledge, skills and inputs. A shift to expensive seeds, in particular hybrid seeds, may even trigger a transition from the use of seed by the farmers to the use of seedlings produced by specialised 'seedling producers' or 'young plant raisers' (Van de Broek *et al.*, 2015). Seedling producers represent further specialisation in the chain raising productivity along with upfront investment costs.

8.4 Farm system

The farm system has been defined as a 'decision-making unit comprising the farm household, cropping and livestock systems that transforms land, capital and labour into useful products that can be consumed or sold (Figure 8.1; Fresco and Westphal, 1988).' The farm household provides labour, capital, land, and other inputs to produce crops and livestock. Farm systems are shaped by ecological and socioeconomic conditions. Ecological conditions encompass the natural environment, while socio-economic conditions are determined by the financial, human, and technological resources available to a farm household. The farm household allocates its resources to different cropping and livestock systems to maximise output. In a development context, farm systems tend to consist of more than one cropping and/or livestock system. One household may manage a home garden to grow vegetables for consumption, which is irrigated manually, a rain-fed field for the cultivation of commercial staple crops and may use communal grasslands for grazing of their livestock. Rotation schemes are an important component of the cropping system.

Fresco and Westphal (1988) distinguish between subsistence- and market-oriented farm systems (Table 8.2). Subsistence systems primarily focus on the production for the farm household and social circle. The level of externally purchased inputs is low as market sales are also low and irregular. Market-oriented systems focus primarily on the production of goods for regular sales. Purchasing external inputs is common as well as purchasing goods for household consumption, although the household will likely produce most of its staples (and perhaps also other food) itself. Farm systems can be interpreted along the spectrum of subsistence to market with increased use of external inputs and land-use intensity. Besides subsistence and market orientation, there are also 'off-farm employment systems.' In these systems, the farming is done by few household

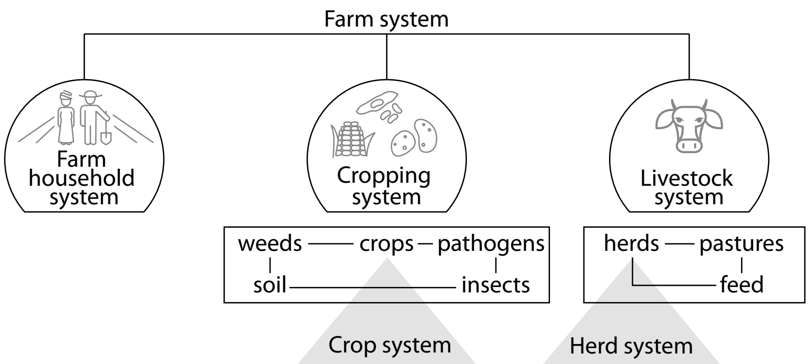

Figure 8.1. Agriculture as a hierarchy (adapted from Fresco and Westphal, 1988).

members as an additional source of income and food supplies. Most household members have a job elsewhere doing agricultural or non-agricultural work.

Some improved varieties can be integrated in existing farm systems, while others will require changes. Adoption may require changes in allocation of financial or human resources to a crop system looking at the costs of inputs or labour. If farmers adopt a high-yielding variety, they should also add fertiliser to maintain soil quality. Alternatively, a variety may require a change in the crop rotation scheme. A resistant variety may enable farmers to grow a crop slightly earlier or later in the season. An example could be an improved variety, which is resistant to a fungal disease during heavy rains or with a shorter growth cycle reducing the risk of contamination. However, a change in one crop system does not stand on its own as it impacts the entire cropping system. If the land needs to be available for another crop or labour is unavailable; a farmer is unable to tweak timing.

8.5 Market system

A market system is a network of sellers, intermediaries, traders, buyers and other actors that come together to trade in a given product or service, in our case either seed or ware. It can be regulated or not. The market system through which produced crops reach the consumer, dictates standards for variety traits and product quality. These standards have an impact on cultivation techniques and post-harvest practices applied. Also, the market system sets the price of products, which determines the potential return on investments in inputs and production practices. Farmers participate in different markets systems for different crops. Sometimes, they are part of two systems for the same crop selling different quality levels for different prices. Farmers make individual choices tailored to their household situation, weighing their resources, risks, and potential benefits of different market options. They can switch between market systems if they can meet quantity and quality standards. It should be stressed that market access itself continues to be a key challenge for many smallholders.

De Steenhuijsen Piters *et al.* (2021) distinguish between four types of consumers in a development context: rural consumers, low-income urban consumers, middle-income urban consumers and high-income urban or foreign consumers. Rural consumers can produce their own food and/or purchase food on local informal markets. Urban consumers do not produce their own food and will buy their food on informal or formal markets. In developing countries, the high-end formal market channels only represent a fraction of the total market. In informal market systems, standards tend to be unregulated, and agreements are based on social networks and kinship

Table 8.2. Overview of two generic types of farm systems.

System orientation	Subsistence	Market
Primary focus of farm system	Household consumption	Household income through market sales
Use of external inputs	Low level of external inputs	High level of external inputs
Land-use intensity	Low	High

relations. In formal market systems, standards are more regulated, and agreements are made between registered businesses working with contracts. The systems in Table 8.3 are based on the work of De Steenhuijsen Piters *et al.* (2021). They show an increasing distance between producer and consumer, which results in standardisation and higher quality requirements. Quality in subsistence farming is linked to household needs whereas quality on export markets is defined by international standards.

Benefitting from adopting a new variety might be possible without making any changes in the market systems the farmer is navigating. A more disease-resistant variety may simply enable the farmer to reduce the risk of crop losses and increase productivity and hence, marketable surplus. Moreover, a more disease-resistant variety can enable a farmer to plant slightly earlier or later avoiding the main harvest period. The varieties can deal with less or more rain and associated pressure of diseases and pest. As a result, farmers avoid the price drop during the main season and can sell for a higher price. For other variety benefits, a shift in the market systems may be required. In developing countries, most farmers do not participate in a market system where quality premiums apply for traits such as longer shelf-life or better taste. In local spot market systems, price differentiation for different quality grades or different varieties is often not very pronounced or inexistent. In both informal and formal market systems it is challenging to introduce a new variety with different traits than consumers are used to (taste or skin colour) or a change in packaging, collection, wholesale, or retail practices.

8.6 Application to case studies

Changes often represent barriers for adoption of the innovation. The successful introduction of a new crop variety entails that a farmer decides to change his or her practices because promises outweigh barriers. A prerequisite for technology success, or adoption is that the promises of the technology will materialise for a farmer. We consider the magnitude of the systemic changes required as an important indicator of the chances of successful technology introduction. We analyse these for the seed, farm and market systems separately pinpointing promises and barriers. In the two case studies below, we look at promises of an innovation and weigh these against the system changes required for adoption. The goal is to extract lessons for the introduction of HTPS in a development context in a structured manner looking at the three systems.

Table 8.3. Overview of three generic types of market systems.

	No market	Informal market	Formal market
Market system	Home consumption	Local markets	Local and export markets
Consumer type	Rural consumer	Low and middle-income urban and rural consumer	High-income urban or foreign consumer
Type of crop	Local crops	Local and global crops	Global crops
Quality level	Low quality or 'quality matching household need'	Low and medium quality including rejects from formal market	High quality meeting national or foreign standards

8.6.1 Seeing is believing: tomato in Tanzania

EWS, Rijk Zwaan and Wageningen University & Research joined forces to introduce improved tomato varieties as part of the Seeds of Expertise for the Vegetable sector of Africa project: SEVIA (Mwashayenyi, 2022). EWS and Rijk Zwaan are both Dutch family-owned vegetable breeding companies. Rijk Zwaan focuses on hybrid varieties for more temperate conditions. EWS has both hybrids and open-pollinated varieties (OPVs) in its portfolio suited for tropical climates. The goal of SEVIA was to stimulate adoption of improved vegetable varieties including tomato and to build farmer capacity to unlock the potential of these varieties. Tomato was the key focus being the main commercial crop for most vegetable farmers. The partners could build on their shared expertise and experience in tomato breeding, cultivation, and extension. The SEVIA project started in 2013 and ended in 2020.

8.6.2 Starting point

Tomato producers often use farm saved-seed, purchase seed on local markets or acquire seed at a seed shop or agro-dealer. Farm-saved seed is often harvested from bad fruits, which cannot be sold on the market. Farmers do not realise that the quality of the tomato fruits is an indicator of the genetic, physiological, and physical quality of the seed. They should save seeds from their best rather than their worst plants and fruits. Seed sold on local markets generally has a better quality, because it is clean and produced professionally. The price of a package is based on the number of grams or the number of seeds. The quality of seed sold on markets, locally sourced, or in seed shops, nationally sourced, is still uncertain (Guijt and Reuver, 2019). Farmers are at risk of buying counterfeit seed or seed, which has been repacked or stored under bad conditions. Either way, poor quality seed results in low germination and low plant vigour. Moreover, uncertain seed quality disincentivises farmers to invest in cultivation.

Tomato is an important part of the farm system as it is a key source of income. However, tomato production is also a tricky business. On average, tomato farmers face major losses once every five years (Guijt and Reuver, 2019). These losses are often caused by production conditions such as diseases, pests, excessive rain, or droughts. Disease such as late blight or bacterial wilt can have a devastating impact. Currently, most farmers mitigate risks by planting a smaller plot of tomatoes and/or minimising their production costs with a low-input strategy (Guijt and Reuver, 2019). Very few farmers invest in a greenhouse, which allows for better control of agronomic conditions, resulting in lower crop losses. Greenhouses are more commonly used for sweet pepper than for tomato production.

Moreover, many farmers lack the knowledge, skills, and technologies required to improve their tomato production. Plants, which are left to lie on the ground will never be as productive as vine or bush plants, which are supported by trellises to grow tall. These plants are vulnerable to diseases and pests as they are close to the soil and their leaves stay wet. Also, farmers often do not know which crop protection and fertiliser to apply and how to do so while protecting the plant's health and their own. Farmers tend to use standard fertiliser throughout the season, which might not match the soil or needs of the crop at certain growth stages. Similarly, standard mixes for crop protection are applied without considering the specific disease threat.

Most Tanzanian farmers grow tomatoes during the same period, as they depend on the rains to water their field. Tomato cultivation takes place during both rainy seasons: the long rainy season runs from March until May and the short rainy season from October until December (Guijt and Reuver, 2019). Viruses, fungi, and bacteria all pose a major threat (Everaarts *et al.*, 2011). Off-season production is challenging because it requires reliable access to water. Consequently, the market is flooded with tomatoes during harvest time. Farmers must all sell at the same time because once the fruits have ripened, there is only a limited timeslot to get them to the market.

During transportation, tomatoes are easily damaged because of the soft skin. Traders anticipate losses during transportation and at the market (Sibomana *et al.*, 2016). Hence, they want to buy in bulk at a low price. Most tomatoes are sold on fresh markets in rural and (semi-)urban areas. On these markets representing over ninety percent of sales, there is no price premium for quality. The high-end tomato market where premiums are paid, including supermarkets, restaurants, and hotels, is estimated to represent about one percent (Guijt and Reuver, 2019).

8.6.3 Promise of innovation

The innovation brought to Tanzania by EWS and Rijk Zwaan was high-quality seed of improved OP and hybrid tomato varieties. Seed is produced through a specialised chain in accordance with the company standards, which are stricter than national standards. In terms of physiological quality, germination rates are close to a hundred percent. The varieties were tailored to local conditions and harboured many disease resistances raising the yield potential in comparison to common popular varieties. In general, varieties of EWS are more suitable for small-scale farmers growing tomatoes in the open field (Figure 8.2). Varieties of Rijk Zwaan tend to be a better match for large-scale farmers or high-tech growers using greenhouses.

Figure 8.2. Farmer showing his trellised tomato plants in Tanzania.

The formal brand and delivery method serve to communicate these traits to farmers and ensure them of seed quality. In informal seed systems, a degree of uncertainty always remains regarding quality. When developing a distribution network, seed companies need to build trust in the system in general and in their brand in particular. Rijk Zwaan does this by selling seed directly to customers or working with a selected partner. In this way, it can exercise strict control. EWS builds relationships with agro-dealers and seed shops providing training to those retailing its seed. In this way, it tries to ensure quality control along the chain. In Tanzania, EWS developed its sales channels via an existing brand, Mkulima Seed, which it acquired.

Improved tomato varieties serve to massively increase marketable yield. Everaarts *et al.* (2011) report tomato yields of 0.5-0.7 kg/m^2. Provided that farmers apply good agricultural practices, yields can increase by a factor 3 to 5 (East-West International BV *et al.*, 2020). Tomato yields of 2.5-7 kg/m^2 in the field and 25 kg/m^2 in greenhouses were reported. The varieties are less affected by pests and diseases and, hence, the risk of losses is lower. Moreover, some varieties also have a shorter growing period reducing the risk of contamination. Even when farmers invest less time and money in crop protection, resistant varieties might perform better than traditional ones.

8.6.4 Barriers to adoption

Still, it can be challenging for farmers to switch from farm-saved or locally sourced to globally sourced seed of EWS and Rijk Zwaan. The price of seed of improved varieties is high when compared to seed bought via informal channels. Farmers who save their own seed are not used to paying for seeds at all. A higher seed price increases the upfront cash investment required of producers. Also, it increases the risk of losses when something goes wrong during the season or during marketing of produced fruits. First, farmers need to have cash available and second, they need to be able to cope with these risks. Moreover, the increase in price might entail a switch of paying per gram of seed to paying per individual seed.

The high germination rates of quality seed are realised when farmers apply the recommended seedling raising practices. Raising strong seedlings requires farmers to invest in sterile planting media, trays, and a nursery infrastructure, which adds further costs. When a farmer plants good seed in bad soil, the investment is likely wasted. Alternatively, farmers can buy seedlings from a specialist farmer, a seedling producer. In this way, they avoid all risks associated with the nursery stage. The farmer has now switched from paying a price per gram of seed, to paying per seed, to paying per seedling. Again, the upfront investment increases as seedlings are significantly more expensive than seeds.

Realisation of the genetic potential of improved varieties requires the application of good agricultural practices. Without additional care, an improved variety might still outperform a local variety, but a farmer is unlikely to earn high returns on the investment. Some good agricultural practices can be applied without additional costs. One example is correct spacing of plants. The right plant density maximises the number of plants but makes sure each plant still has sufficient room to grow. Another example is a raised plant bed, which improves drainage and protects the plants from 'wet feet' during heavy rains. Raised beds require additional effort, but no additional costs. Similarly, careful monitoring of pests and diseases takes skills and time, but it enables farmers to reduce pesticide and fungicide use optimising benefits from disease resistance. Other practices do entail additional expenses. The high costs of an irrigation pump, tunnels or a greenhouse are obvious. However, trellises also require farmers to buy or collect sticks increasing production costs. Sticks have a market value and could otherwise be used as firewood.

If farmers want to get a better price for their tomatoes, they need to avoid the main harvesting period and tweak their timing. However, most farmers have a tight rotation schedule, which might not leave room for change. On the market, there are barely any rewards for improved fruit quality. Over 90% of tomatoes produced in Tanzania are sold on local urban or rural fresh markets (Guijt and Reuver, 2019). On these markets, there is a fixed price per kilo. Price premiums are only paid on the high-end market, which represents around one percent of the market (Guijt and Reuver, 2019). Usually, farmers are dependent on traders or 'brokers' who come to pick up their harvest at the farm (Everaarts *et al.*, 2011). Improved quality and uniformity of fruits may help farmers build a stronger relationship with a trader or a broker. During peak-production season, when the market is overflown, a reputation for quality fruits with the desired ripeness, colour, thickness of skin and absence of damage or blemishes is an advantage as traders are looking for robust fruit with a good shelf-life.

8.6.5 Strategies applied to overcome barriers

The general objective of the SEVIA project was to provide farmers with access to improved varieties as well as the knowledge, skills and technologies required to maximise the benefits gained from adopting these improved varieties (Mwashayenyi, 2022). SEVIA was a 7-year and 9.5-million-euro operation, which gives an indication of the time and resources required to initiate a transition. The project supported the development of applied research and training centres, implementation of variety trials, organisation of farmer field demonstrations, and capacity building of professionals. Basically, the project partners developed an outreach programme to build their own market creating demand for improved tomato varieties.

A local team of agronomists and station workers was trained by Wageningen Plant Research. Improved varieties were tested first on SEVIA's demonstration farm (Mwashayenyi, 2022). In this way, local trainers could gain experience with the new varieties and techniques. Demonstrations were organised throughout the country and a snow-ball effect was initiated building on farmer-to-farmer dynamics in communities. To offer farmers the option of buying seedlings rather than seed, ten lead farmers received nursery management training and support, including access to credit, to specialise as seedling producer. Other farmers were trained to produce strong seedlings themselves at their farm. They preferred doing their own seedling production to avoid high production costs. Besides good agricultural practices, planning of and calculations for production were important modules in the farmer trainings. Farmers were also encouraged to shift the timing of their production tapping into better market prices.

In 2020, at the end of the project, training had been provided to more than 48,000 farmers and 1,400 sector professionals (East-West International BV *et al.*, 2020). The impact of SEVIA on tomato production is visible in the targeted project areas. Previously, use of improved varieties by Tanzanian tomato farmers was very limited. Nowadays, the use of improved OPVs and hybrids has become more common. Out of ten trained lead farmers, four ended up setting up a seedling nursery business and now sell young plants to their peers. Prior to SEVIA, no seedling nurseries existed. Nowadays, trellises can be spotted in farmer fields in the targeted areas. Impact on farmer livelihoods is difficult to measure. Still, growing seed sales reported by EWS and Rijk Zwaan can give an indication of adoption and hint at lasting change.

8.6.6 Conclusions

The SEVIA project theme was seeing is believing. The goal was to show farmers how to unlock the potential of improved varieties. This approach seems to have worked for some farmers who are shifting to hybrid varieties and adopting new agricultural practices. It seems likely that adoption and system transformation are driven by a large, established market for tomatoes. Farmers are motivated to adopt and invest in innovations to tap into this market making them willing to change. In the absence of premiums for quality, farmers will focus on quantity, which may be unsustainable in the future. The tomato market will not expand forever: farmers need to be able to compete on other quality factors and diversify their production moving into other crops.

However, obstacles to the adoption of improved tomato varieties certainly remain for small-scale farmers. These are related to knowledge gaps and financial resources. Capacity building is needed to teach farmers about good agricultural practices. Basic skills and technologies are required to unlock the full potential of improved varieties. Also, farmers need to be able to invest in seeds, inputs, and equipment. They will move step-by-step selecting varieties and feasible agricultural practices, which match their livelihood. During SEVIA, farmers received training regarding the full package, but in the end, they will decide for themselves what is feasible and affordable.

8.7 Reinventing rather than transforming: shallots in Indonesia

De Groot & Slot is the global market leader in onion and shallot seed. It works closely together with the Dutch vegetable breeding company Bejo, which covers a wider variety of crops and has a strong global presence. In 1995, De Groot & Slot was the first to apply the generative seed multiplication and breeding system of common onion to shallots. The innovation of hybrid true shallot seed (TSS) was first introduced in Europe, after which the companies shifted their attention to Indonesia. The shift from shallot bulbs to (hybrid) TSS requires a transformation of the seed, farm, and market system. In the past years, De Groot & Slot and Bejo have experimented with different strategies and undertaken several projects to introduce their innovation in a development context.

8.7.1 Starting point

Traditionally, shallots are multiplied vegetatively, offering farmers a relatively simply way to grow their own seed. Small shallot bulbs attached to the main bulb are harvested, stored for about eight weeks to overcome bulb dormancy, and used as seed for the next planting season. The shallot seed system is largely informal, based on this process of recycling one's own material and exchanging or trading of seeds with neighbours to get access to new varieties. The system fails to supply sufficient quantity and quality of shallot seed: each growing season, shallot farmers face shortages.

Quantities of seed available are too low due to high losses. Storage losses reach 40%, especially during the rainy season when disease pressure peaks. Anticipating these losses, some farmers save a large share of their harvested crop as seed. Other farmers in urgent need of cash are unable to do this and need to sell their harvest. The quality of seed bulbs is another major challenge. Quality of vegetatively multiplied bulbs deteriorates over seasons due to a build-up of pests and diseases that survive in the bulbs (so-called degeneration). Viruses are a particularly big problem in vegetatively propagated shallots, resulting in small plants and low yields. Exchange of seed between farmers can result in the transmission of diseases. Moreover, international seed bulb exchange creates a risk of cross-border transmission.

In response to persistent shortages of shallot seed bulbs, Indonesia imports these from neighbouring countries such as the Philippines, Vietnam, and Thailand. These countries have a different rainy season and can export seed bulbs to Indonesia shortly after their harvest right on time for planting. As a result, imported seed bulbs are cheaper and often better than local ones, as the storage time is much shorter. In this case, cheaper should be interpreted as 'less expensive' as international transport is costly. Seed bulbs can account for up to 50% of shallot production costs. Also, the imported shallots mostly benefit Indonesian farmers located close to ports, while farmers in remote areas continue to struggle to access seed.

Many Indonesian farmers grow shallots (Figure 8.3): it is the second largest horticultural crop after hot pepper. Shallots are grown during the dry season running from March to October. During

Figure 8.3. Shallot farmers working in the field in Indonesia.

the dry season there are two growing periods. Both seasons require reliable access to water for irrigation. At the end of the dry season, rivers and wells tend to run dry. During the rainy season, few farmers grow shallots because of high disease pressure. Shallots are mostly grown in very heavy soils at sea level. The weight of the soil makes shallots grow slowly increasing their shelf life.

Local demand for shallots is enormous. On average Indonesians consume 4.5 kilo of shallots per capita per year. The French consume 550 grams of shallots per year, and the Dutch merely 85 grams. In 2013, Indonesia introduced an import ban on shallots to stimulate domestic production. The price of shallots rose from 90 eurocents to almost 3 euros per kilo. Financial and physical access of farmers to shallot seed for cultivation and consumers to shallots for consumption was reduced.

8.7.2 Promise of innovation

The promise of TSS compared to seed bulbs is that high quantities of high-quality seed can be produced faster, cheaper, and easier. A single shallot plant produces only six to ten bulbs, whereas it can also set up to 200-600 true seeds under optimal conditions. The high multiplication rate of TSS means associated costs of seed production can be reduced. Contrary to bulbs, true shallot seed is generally free of pests and diseases. All logistical issues of bulbs related to storage or transportation are removed as true seeds are easily stored and shipped. The innovation of true shallot seed results in a constant and reliable supply of quality seed, which can be planted whenever the barrier of dormancy is removed.

The hybrid variety 'Maserati' can outyield local varieties by over 30%. This increase in yield is explained by the clean nature of the starting material and improved genetics of the hybrid variety. As the true shallot seed is free of pests and diseases, the plants have a good start and turn out healthier. Strong genetics improve the chances of the plant surviving under pressure from pests and disease. In the hot and humid Indonesian climate, farmers still need to spray, and there is no cost reduction. Still, farmers see the added value of the hybrid: De Groot & Slot and Bejo also sell true shallot seed of an OP variety, but this one is much less popular amongst farmers.

In industrial agricultural systems, (hybrid) true shallot seed offers another benefit. The uniformity of true shallot seed supports mechanisation. Bulb shallots still require manual labour during planting and harvesting, which is costly. By contrast, seed shallot production can be partially mechanised. This benefit is less relevant in a development context where the cost of manual labour is low, farmer fields are small, and mechanisation of agricultural production is limited.

The taste and colour of seed and bulb shallots are similar. However, the quality of seed shallots is either similar to, or higher than the quality of bulb shallots. Shallots grown from seed tend to be more uniform and larger than bulb shallots, which are usually small due to viruses. Bulb shallots are usually the size of a large garlic clove. Consumers prefer larger shallots because they need to peel less. Also, the shelf life of seed shallots tends to be longer than of bulb shallots. A shallot can be stored when it ripens without being contaminated by diseases or pests. Use of clean starting material and production in clean soil are the most effective ways to mitigate the risk of contamination.

8.7.3 Barriers to adoption

Currently, shallot farmers do not buy their plant material from agro-dealers or in seed shops. In fact, formal market channels to sell shallot seed bulbs are non-existent. Farmers are used to saving their own bulbs, exchanging bulbs with neighbours, or buying bulbs through the informal market. In this system, the reputation of farmers and geographic areas play an important role. One of the few means available to verify quality was for farmers to undertake field visits, visually check the state of the shallot plants and decide from whom they would buy bulbs.

The shift from using shallot bulbs to true seed also represents a major hurdle. It is cumbersome for shallot farmers to switch from using bulbs to using true seed as planting material. Shallot farmers are used to robust bulbs, which are planted directly in the field. The true seeds are planted in a nursery and after 6-8 weeks, the seedlings are transplanted to the field. Alternatively, true seed can be sown directly in the field, but the plants will take longer to mature. Shallot farmers have no or very little experience with germinating seeds, raising seedlings, and transplanting seedlings.

Moreover, shallots grown from true seed thrive in other soils than shallots grown from seed bulbs. Traditional production areas are characterised by heavy clay soil and heavy rainfall. By contrast, true seed shallots flourish in lighter soil, as they struggle to establish their root system and emerge and need moderate rains. Also, there are doubts regarding the performance of new varieties under high soil-borne disease pressure which characterises the traditional production areas. Even though hybrid shallots are grown from clean seed, many resistances are needed to grow under these conditions. For many years, local varieties have been selected by farmers, which can cope with high disease pressure.

Finally, the use of true seed impacts the plant growth cycle. One of the first questions of farmers about a new variety is: how much time will it take me to grow the crop? In Indonesia, farmers have strict rotation schemes as they have three growing seasons per year. Plants grown from directly sown shallot seeds take 3-4 weeks longer to mature clashing with a farmer's planning. Seedlings are produced in a nursery and the growing period in the field remains the same. Therefore, the introduction of TSS via seedlings is possible while direct sowing is likely not an option.

Few barriers to adoption seem to exist related to the market system. In terms of varieties, the shallots grown from true shallot seed should be at least equally popular. A study conducted in 2012 by Van den Brink and Basuki stated that consumers prefer traditional varieties with a deep red colour over improved varieties with a lighter skin colour (Van den Brink and Basuki, 2012). However, the main hybrid variety of De Groot & Slot and Bejo called Maserati also has a deep red colour.

8.7.4 Strategies applied to overcome barriers

De Groot & Slot and Bejo applied two different strategies to introduce TSS. First, they sought to launch a bulb-based system producing bulbs from true seed. The aim was to minimise change for the shallot farmer supplying seed bulbs to market and not true seed. They invested in a farm in

Thailand to grow bulbs for the Indonesian export market. Production of shallot bulbs from true seed would be done internally on farm, and subsequent rounds of multiplication would be done by outgrowers. The harvest could be shipped to Indonesia directly after the rainy season. In 2013, after several years of testing to optimise the production, the companies and their outgrowers were ready to export. However, around this time, the Indonesian government decided to implement an import ban on shallots. Previously, 30% of Thai shallots were shipped to Indonesia.

While Thai market prices crashed, Indonesian market prices peaked. The companies decided to move their operations to Indonesia. They figured that scarcity and high market prices could fuel technology adoption. Also, they decided to go for a radically different strategy: there would be no investments in vegetative multiplication. Moreover, the focus would not be on traditional shallot areas and traditional shallot farmers. In 2017, the company identified the most suitable cultivation areas for shallots grown from (hybrid) true seed together with Wageningen University & Research. In these areas, vegetable farmers were targeted to include shallot production into their rotation schemes. The fields with lighter soils were suited for seedlings and farmers already had experience working with seedlings growing other horticulture crops.

In 2018, a project funded by the Dutch Enterprise Agency (RVO) was implemented to establish a training centre, organise demonstrations for farmers and supply free seed samples. De Groot & Slot and Bejo invested in capacity building of farmers in shallot cultivation using a farmer-to-farmer training model. De Groot & Slot says: 'they shifted from investments in hardware to investments in software.' The vegetables farmers were unfamiliar with shallot cultivation. They are now training these farmers to cultivate shallots from true seed. Farmers will be able to tap into the massive domestic market and simultaneously, seed companies expand their customer base. In the coming years, Bejo and De Groot & Slot expect a snowballing effect to commence as other farmers learn about the potential of true shallot seed. High prices provide a strong incentive to grow shallots and adopt innovations to increase productivity.

The new strategy of De Groot & Slot and Bejo has yielded considerable success. The companies have now been promoting (hybrid) true shallot seed in Indonesia for 5 years. Currently, about three to five percent of area under shallot production is planted with true seed. Worldwide, De Groot & Slot and Bejo have a market share of 50% in long-day shallots and hence, they are not satisfied. In the coming years, the two companies aim to increase their market share in Indonesia. De Groot & Slot and Bejo stress that it took twenty years to realise the 50% market share in Europe. The five-year timeline in Indonesia is still relatively short.

8.7.5 Conclusions

The transformation of the shallot seed, farm and market system turned into a reinvention of these systems. Initially, De Groot & Slot and Bejo sought to minimise change for traditional shallot farmers. The companies then decided to take a radically different approach targeting new areas and farmers. A research project preceded the design of its market strategy identifying the most suitable areas, which turned out to not to be the traditional shallot areas. De Groot & Slot and Bejo have focused on capacity building and aim for a snowball effect. As farmer communities in new areas become more familiar with shallot cultivation, they expect their market share to grow. The large domestic demand for shallots is a strong force for adoption. Nowadays, their market share of the Indonesian market is estimated to be around five percent, which is considerable, but insufficient for global market leaders in allium crops.

The key remaining barriers to adoption are financial ability, knowledge, and skills. First and foremost, many farmers still cannot grow shallots because of the high upfront investment costs: the costs of seed bulbs are simply too high. True seed can somewhat reduce and stabilise the price of starting material enabling more farmers to grow shallots in remote shallot areas. However, many farmers still cannot afford to adopt innovations. Second, farmers need to be familiarised with good agricultural practices. Increases in national shallot production are based on expansion of the cultivation area rather than yield gains. The hybrid variety Maserati has major potential, but farmers need knowledge and skills to realise this potential. As long as yields are low, the return on the investment of farmers in seed also remains low.

8.8 Disruption or integration: hybrid true potato seed in East Africa

HTPS technology has the potential to become a disruptive innovation. The potential impact of HTPS on the potato sector in developing countries is high (De Vries *et al.*, 2016). HTPS offers an alternative for the current potato seed system based on tetraploid varieties, which are cumbersome to improve genetically using conventional breeding methods, and which are multiplied slowly through vegetative seed potato production systems (Jansky *et al.*, 2016; Lindhout *et al.*, 2018). Still, HTPS introduction will require either integration of HTPS in existing potato seed, farm and market systems or transformation of these systems, which may prove challenging. The first commercial hybrid potato varieties are becoming available now being introduced on the market by Bejo (tetraploid TPS) and Solynta (diploid hybrid TPS). The first commercial varieties of Aardevo and HZPC are expected in 2025. It raises the question how the innovation can effectively be introduced in a development context.

8.8.1 Starting point

Potato farmers in the Netherlands can produce 42 tons per hectare, whilst average yields in East Africa are around seven to twelve tons per hectare (FAOSTAT, 2020). Potato productivity has only improved marginally over the last decades, and the growing demand is met by area increase, rather than productivity increase (Gildemacher *et al.*, 2009b). This has resulted in a situation where the maximum areas under cultivation which can be considered sustainable in terms of soil health management have been surpassed. Further growth of production will have to be realised through productivity increase in the traditional highland production areas.

Traditionally, potatoes have been multiplied vegetatively. Farmers use seed tubers as starting material for potato production; some tubers are saved and used to grow new plants. In East Africa, more than 90% of the seed tubers is provided via the informal seed system (Gildemacher *et al.*, 2009a; Schulte-Geldermann *et al.*, 2022). The most common source of seed tubers is self-supply, selecting and storing small tubers from the previous harvest. Farmers also exchange or trade seed tubers within their social network. Only a tiny proportion, 2-5% of seed tubers, is sourced via the formal system from specialised farmers adhering to a quality control system (Ferrari *et al.*, 2018; Gildemacher *et al.*, 2009a). High-quality potato seed tubers tend to be expensive or unavailable. A major financial barrier exists to buy certified seed as costs would account for up to 60% of total production costs (Schulte-Geldermann *et al.*, 2022).

The low quality of potato seed has been identified as a key constraint contributing to low productivity. Quality of seed tubers decreases every cycle of vegetative multiplication due the accumulation of soil- and seed-borne diseases and pests and contributes greatly to the perpetually low yields of smallholder potato farmers in East Africa (Schulte-Geldermann *et al.*, 2022). From this amount, around 20% of the tubers are saved by farmers as seed for next season further lowering their marketable surplus.

Losses during storage period can reach up to 30% (Gikundi *et al.*, 2022). In Kenya, the popular variety 'Shangi' already sprouts two weeks after harvest to avoid a storage period (Gikundi *et al.*, 2022). Managing tuber dormancy is a major element in the potato production, as the moment of sprouting needs to match the desired moment of planting. This complicates considerably the seed potato system for professional seed producers, seed users and breeders alike.

In East Africa, potatoes are almost exclusively grown by smallholder producers, as landholdings in the highlands suitable for potato production are highly fragmented (Devaux *et al.*, 2021). Amongst farmers, there is a lack of awareness regarding good agricultural practices, disease and pest control and soil fertility. Potato farm systems in East Africa are generally 'low input,' in comparison to industrialised systems. In East Africa, it is mostly grown under rain-fed conditions and the majority of smallholder producers uses sub-optimal crop protection and soil fertility management.

Potato is an important food and cash crop in East Africa. The market can be divided into two segments for ware versus processing potatoes. Ware potatoes are bought by consumers, whereas processing potatoes are used to produce crisps or French fries. In developed markets, these are strictly separated, while in developing countries, they tend to largely overlap. Market prices are subject to large fluctuations. Farmers do not grow potatoes during the off-season because of a lack of irrigation facilities. During the harvesting period, prices drop as market is overflown. Before the start of the new season, supply runs low, and prices go up. Meanwhile, demand for potatoes continues to grow because of population growth and changing diets, which can be linked to urbanisation.

8.8.2 Promise of innovation

An immediate benefit of HTPS technology is the possibility to grow potatoes from true seed rather than seed tubers. So far, little progress has been made in developing effective vegetative seed systems that serve smallholder producers in developing countries with affordable high-quality seed tubers (Schulte-Geldermann *et al.*, 2022; Tadesse *et al.*, 2020). The benefits are comparable to the benefits of (hybrid) true shallot seed moving from a vegetative to a generative seed system. A transition from the vegetative to the generative seed system allows for much faster multiplication, reducing the number of multiplication generations from up to eight to a maximum of two (Ter Steeg *et al.*, 2022). Less land is required for seed multiplication, risks of crop losses and quality deterioration are reduced. HTPS can be stored for a long period of time in a (dry) cupboard instead of a high-tech storage facility. Also, true seed is transported in an envelope rather than containers, cars, sacks, or crates. In summary, the availability and affordability of starting material for potatoes can radically increase.

HTPS is free from almost all diseases and pests, contrary to the vegetatively multiplied shallot bulbs and seed potato tubers, which tend to be contaminated by seed-borne diseases (Kreuze *et al.*, 2020). The seed- and soil-borne disease bacterial wilt is endemic in East Africa. Use of clean seed is essential for its containment and flush-out over time. However, production of clean seed is sheer impossible when multiplying seed tubers vegetatively in an environment in which disease-free land can hardly be found. HTPS can break the cycle of seed- and soil-borne re-infection. Potato viruses are another major yield reducing factor and accumulate in seed stock over generations of re-use. In East Africa, many potato plants in farmer fields look different. Heterogeneity is caused by high virus disease incidences. Regular renewal of the seed stock with virus-free material from HTPS will mitigate this problem.

Improved varieties with stronger genetics can now be developed for potatoes. Hybrid breeding could not be applied in traditional tetraploid potato varieties due to their genetic complexity (Jansky *et al.*, 2016; Lindhout *et al.*, 2011). A shift to the diploid potato made it possible to add desirable new traits to existing varieties reliably and effectively (Su *et al.*, 2020). In both the tomato and shallot case, the added value in terms of stable and uniform yields were major drivers for adoption amongst farmers. Moreover, like tomato, potato is a vulnerable crop and fields can be wiped out by certain diseases. Resistance to late blight, to viruses such as PVY, PVX, PLRV, and to nematodes such as PCN will play an important role in variety selection. Moreover, resistance to abiotic stresses such as drought will only continue to become more important in the future.

Varieties can also be tailored to specific market demand. In East Africa, processors often resort to buying 'multi-purpose' table potatoes because local processing varieties are unavailable (Placide *et al.*, 2022). New hybrid varieties can fill this gap. Processors are looking for a specific tuber shape, a smooth skin, shallow eyes, low sugar levels and a high dry matter concentration. However, specialised production will only be viable if processors are willing to pay a tangible price premium to producers. Otherwise, farmers prefer the consumption spot market, which is generally a more convenient and reliable offset channel.

8.8.3 Barriers to adoption

Many of the barriers to adoption resemble those identified for the improved varieties of shallots and tomatoes. The main barrier is similar to the one faced for true shallot seed seeking to change the type of starting material. Potato and shallot farmers are used to robust vegetative starting material. True seed requires more care. Ideally, it is planted in a nursery to raise seedlings, which are transplanted to the field 4-6 weeks after sowing (Kacheyo *et al.*, 2020, 2023). The vast majority of potato and shallot farmers has no experience germinating seeds, raising seedlings, and transplanting seedlings. Especially during the first few weeks, seedlings need to be nurtured. Apart from low early vigour, seedlings are sensitive to weed infestation, wind erosion, earthing up and damping off.

Also similarly, no large-scale formal seed systems for potato currently exists and farmers may not be reached easily. A limited number of seed potato multipliers exists, who buy pre-basic seed tubers which they multiply several generations before selling to producers. Sales of seed tubers rather than true seed or seedlings would minimise the change for traditional potato farmers. However, this would increase the upfront investment of farmers and the tomato case showed how farmers prefer to raise their own seedlings to reduce costs. Furthermore, this would either require existing multipliers to learn how to deal with seedlings. Alternatively, it would require young plant raisers to learn how to deal with potato plants. Therefore, integration of HTPS into existing systems requires potato seed multipliers to learn horticultural skills or young plant raisers to familiarise themselves with a new crop.

It might be hard to introduce HTPS in traditional potato farm systems. In traditional areas, soils tend to be heavy and cropping systems are rain-fed (Mazengia *et al.*, 2015). Potato farmers have limited or no access to other water sources, while irrigation is generally necessary for root establishment of HTPS seedlings. Direct sowing of HTPS might be an option in the future, for example thanks to seed coatings, but this would mean that the full-field growing period is weeks longer (Van Dijk *et al.*, 2023). It is highly unlikely that farmers then shift from seed tubers to HTPS, as land is a very scarce resource in the East African highlands. It might be the case that reinvention of the potato system elsewhere working with vegetable farmers is easier.

Hybrid potatoes will compete with familiar, local varieties. National potato markets in East Africa are dominated by a limited number of popular varieties. In Kenya, the Shangi variety dominates the market with a share of over 80% and in Rwanda, the Kinigi variety holds a similar position (Gikundi *et al.*, 2022, Irungu *et al.*, 2022; Muhinyuza *et al.*, 2012). Farmer, trader, and consumer preferences are strong and when it comes to table varieties, consumers prefer large tubers with a familiar skin and flesh colour (Muhinyuza *et al.*, 2012). The most popular varieties are multi-purpose varieties, which can be used for boiling, but also reasonably well for frying. Personal experience of the first author indicates that cultivation from HTPS via seedlings can result in a higher number of smaller tubers in comparison to potatoes grown from seed tubers. Farmers or specialised multipliers may have to include one round of vegetative multiplication in the seed system to assure the desired tuber size is harvested (Figure 8.4).

8.8.4 Proposed strategy to overcome barriers

When considering seed system barriers for the adoption of HTPS, the main barrier is the cumbersome raising of seedlings. Either farmers need to learn how to raise seedlings, or specialisation of the chain is required working with intermediaries. The tomato case shows that the SEVIA project focused both on the training of farmers to grow seedlings in an on-farm nursery,

Figure 8.4. Rwandese farmer planting potato seedlings in the field.

and of specialised seedling producers. Most farmers preferred to grow their own seedlings to reduce costs. In the case of HTPS, there is an option of specialised multipliers to produce seed tubers from HTPS to sell to potato farmers minimising change. This was the initial strategy used for shallot bulbs produced in Thailand for introduction in Indonesia, but unfortunately, no lessons can be learned, as it never got off the ground because of the import ban that was installed.

An advantage is that HTPS is not entering a perfect seed system. Currently, potato starting material is often unavailable and/or unaffordable. In the shallot case, farmers deal with a constant lack of quality seed. In both the shallot and tomato case, farmers deal with uncertainty regarding seed quality. For tomatoes, analytical quality of seed can be low resulting in low germination. Farmers needed to pay a higher price for hybrid seed of improved varieties representing a barrier for adoption. For shallots, physiological quality of seed is low resulting in low yields. Farmers can now pay a similar or lower price for hybrid seed of improved varieties representing a driver for adoption. This can be similar for HTPS: companies can make quality seed available to farmers at similar or lower price level.

In terms of farm systems, the main barrier is the compatibility of fragile seedlings with conditions in traditional potato areas. Potatoes are traditionally grown in heavy soils as part of rain-fed, low-input farm systems. In the shallot case, it was more effective to move into new areas and work with new farmers. A study was conducted to identify the most suitable cultivation areas and develop an effective introduction strategy. Based on the results, the companies decided to focus their investments on the capacity building of vegetable farmers. A similar 'land suitability study' was conducted for true potato seed in Indonesia but has yet to be conducted in East Africa.

Potato breeding companies may benefit greatly from a study as it remains unclear whether HTPS technology is best suited for traditional highland potato farm systems or not.

Another barrier in terms of farm systems is posed by the plant growth period. The shallot case clearly shows that farmers are very much focused on growth period. A short growth period may well be one of the most desirable traits looked for by smallholders in East Africa because of extremely high land pressure. Hence, direct sowing of HTPS by farmers is highly unlikely to become a success due to the extended growth period of plants. Larger farms in the lowlands could engage in potato production with direct sowing as land pressure is lower. In this case, potato breeding companies would need to develop varieties, which are suitable for warmer conditions. Beumer and Stemerding (2021) call for the launch of a hybrid potato breeding programme for the lowland tropics.

Market systems can also represent a bottleneck. Visible traits such as skin colour, flesh colour, tuber size and taste, are prerequisites for a variety to become competitive. The shallot case shows that improved varieties should be of similar or higher quality than existing varieties. In that regard it is essential to invest in breeding for local demand, to assure that HTPS varieties that are introduced are competitive at the level of the consumer. HTPS companies could focus on the processing market because of the lack of local processing varieties. However, the tomato case shows how it is easier to focus on the bulk market rather than a high-end niche market as price premiums for quality are still limited or non-existent in developing countries. If potato breeding companies want to focus on this specialised market, they will need to build partnerships with local processing companies to provide price premiums for farmers.

In addition to the barriers mentioned above, there is a regulatory barrier for the introduction of HTPS. Variety registration regulation and seed certification are based on the vegetative multiplication system. The regulation will have to be adapted to accommodate HTPS requiring collaboration with the relevant government bodies. Seed regulations have a national, regional, and international angle. In practice, the national regulations supersede the regional and international regulation. Hence, it would be most pragmatic to start with national regulation, before entering in discussions of regional and international regulation.

8.8.5 Conclusions

HTPS technology has potential to strengthen the smallholder potato sector in Sub-Saharan Africa. It offers an alternative for the current potato seed system based on tetraploid varieties, which are cumbersome to improve genetically, and which are multiplied slowly through vegetative seed systems. In addition, HTPS is easy to transport and store, has no dormancy, and hardly suffers from seed-borne diseases. These significant promises of HTPS could remove constraints plaguing the development of the potato sector in Sub-Saharan Africa. For its successful introduction, stakeholders will need to realise promises of the innovation and overcome barriers to adoption. This chapter analysed promises and barriers looking at the seed, farm, and market system. Efforts of Dutch vegetable seed companies, EWS and Rijk Zwaan introducing improved tomato varieties in Tanzania, and De Groot & Slot and Bejo introducing true-seed shallots in Indonesia, offer lessons learned when developing a strategy for HTPS.

The SEVIA project in Tanzania (2013-2020) demonstrated that main barriers to adoption of tomato varieties were posed by the seed and farm system. The investment in seed of improved varieties was worthwhile, only if tomato farmers improved their full-field production practices, and prior nursery care. There were no barriers regarding the market system, but there were also no incentives for adoption: tomato is mostly a commodity in Tanzania and there is no diversified market. For successful adoption, an outreach programme was needed to train farmers in good agricultural practices and demonstrate the added value of quality seed, as well as investments in setting up specialised nurseries and training tomato producers on seedling raising were key. The 'True Seed Shallot demonstration project' in Indonesia (2018-2020) sought to introduce TSS varieties requiring a transformation of the seed, farm, and market system. The companies decided to promote TSS outside traditional shallot production areas where the potential positive impact of their innovation was larger. Vegetable farmers, familiar with seedlings while unfamiliar with shallots, were trained in shallot production from seed. An outreach programme was required again to train farmers in good agricultural practices and demonstrate the added value of quality seed plus to teach farmers about shallot production.

HTPS, like improved shallot and tomato varieties, requires transformations of the seed, farm, and market systems. Either a nursery step, followed by transplantation of the seedling is required, or direct seeding can be done, but this lengthens the growing cycle, which is tedious. The tomato case shows that most farmers prefer to produce their own seedlings to reduce costs, while others can be served by specialised seedling growers. The shallot case shows that it might be preferable to work with farmers with seedling experience rather than farmers used to bulbs. Specialised HTPS seedling growers could go a step further, and produce seed tubers, in which case ware potato farmers do not need to change their practices. HTPS will also require changes in the farm system as horticultural skills are required to realise the potential of varieties. This finding seems applicable for all improved varieties: without additional skills, adoption of an improved variety is not economical. Market system promises which contribute to adoption are improved marketability and extended shelf life of produce. Also, the ability of farmers to produce outside the main season thanks to short plant cycles and disease resistance can be a driver. In the case of HTPS, processing quality can be an additional beneficial characteristic.

For HTPS, the challenge is to find a balance between disruption and integration. HTPS is introduced in an imperfect, but familiar system. The promises of the innovation can fuel change of the seed, farm, and market system. However, several barriers for adoption of HTPS remain: these barriers are real but seem surmountable provided that the improved variety meets farmer and consumer preferences. The case studies on tomato and shallot demonstrate that it is possible to realise transformation in a relatively short time through the implementation of development projects focused first and foremost on capacity building. Moreover, there needs to be a business case with secure market demand, which farmers can tap into. It is important to stress that the technology also needs to be introduced in an affordable manner: the high costs of quality seed of improved varieties remain a barrier for many risk-averse smallholders. In summary, farmers need to be familiarised with a technology and recognise its profitability. Subsequently, HTPS technology can be mainstreamed in the seed, farm, and market system minimising disruption and maximising innovation.

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