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Case Studies of Roots, Tubers and Bananas Seed Systems

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Kim Jacobsen, Stephen Walsh, and Graham Thiele

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Acronyms and Abbreviations

ADC	Agriculture Development Cooperation
ADERS	Association for the Sustainable Development
AGDP	Agricultural gross domestic product
ALAC	Los Andes Association of Cajamarca
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AYMT	Adapted Yam Minisett Technique
BMGF	Bill and Melinda Gates Foundation
BRAC	Buhemba Rural Agricultural Center
BSV	Banana streak virus
BW	Bacterial wilt
BXW	Bacterial Xanthomonas wilt
CARBAP	Centre Africain de Recherches sur Bananiers et Plantains
CBO	Community-based organization
CBSD	Cassava brown streak disease
CIAT	International Center for Tropical Agriculture
CIP	International Potato Center
CLAYUCA	Consortio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca
CLITA	Voluntary Association Agreement of the Local Consortium for Research and Technical Innovation of the Cassava Chain in Nicaragua
CMD	Cassava mosaic disease
CMD-UG	CMD-Ugandan variant
CRI	Crops Research Institute
CRS	Catholic Relief Services
CSIR	Council for Scientific and Industrial Research
CSR	Corporate social responsibility
CU	Concern Universal
DAES	Department of Agricultural Extension Services
DARS	Department of Agricultural Research Services
DDS	Diocesan Development Services
DFIF	Department for International Development
DLS	Diffused light storage

DoS	Catholic Diocese of Shinyanga
DVM	Decentralized vine multipliers
EAPIC	East African Phytosanitary Information Committee
EARRNET	Eastern Africa Root Crops Research Network
ECOWAS	Economic Community of West African States
ELISA	Enzyme-linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations
FFS	Farmer field school
FG	Farmers' group
FHIA	Fundación Hondureña de Investigación Agrícola
FIPS-Africa	Farm Inputs Promotions Africa Ltd
GLCI	Great Lakes Cassava Initiative
HH	Household(s)
HKI	Helen Keller International
IITA	International Institute of Tropical Agriculture
INIA	Instituto Nacional de Innovación Agraria
INIAP	Instituto Nacional de Investigaciones Agropecuarias
IP	Implementing partner
ISAAA	International Service for the Acquisition of Agri-biotech Applications
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KARI	Kenya Agriculture Research Institute's
KCDP	Kagera Community Development Program
KEPHIS	Kenya Plant Health Inspectorate Service
KIMKUMAKA	Kituo cha Mafunzo ya Kuboresha Mazingira na Kilimo Adilifu
LB	Late blight
MAAIF	Ministry of Agriculture, Animal Industries and Fisheries
MARDI	Maruku Agricultural Research and Development Institute
MARI	Mikocheni Agricultural Research Institute
MFEC	Mogabiri Farm Extension Centre
MoA	Ministry of Agriculture
MoFA	Ministry of Food and Agriculture
MRHP	Mwanza Rural Housing Project
MT	Million tons

NAADS	National Agricultural Advisory Services
NARI	National agricultural research institutes
NARO	National Agricultural Research Organization
NARS	National agricultural research system
NGO	Nongovernmental organization
NRCRI	National Root Crop Research Institute
NS	Negative selection
OFSP	Orange-fleshed sweetpotato
PCR	Polymerase chain reaction
PLRV	Potato Leaf Roll Virus
PMS	Primary multiplication site
PPP	Public-private partnership
PRIICA	Programa Regional de Investigación e Innovación por Cadenas de Valor Agrícola
PS	Positive selection
PVY	Potato Virus Y
QDPM	Quality declared planting material
QDS	Quality declared seed
QMP	Quality management protocol
RAB	Rwanda Agriculture Board
RMCA	Royal Museum for Central Africa
RMT	Rapid multiplication technique
RTB	Roots, Tubers and Bananas
RUDDO	Rulenge Diocesan Development Office
SASHA	Sweetpotato Action for Security and Health in Africa
SILC	Savings and Internal Lending Communities
SMS	Secondary multiplication sites
SSA	Sub-Saharan Africa
SSSA	Seed system security assessment
TAHEA	Tanzania Home Economics Association
TC	Tissue culture
TOSCI	Tanzania Official Seed Certification Institute
ToT	Training of trainers
UCBS-V	Uganda cassava brown streak virus

UIL	Universal Industries Limited
UNA	Universidad Nacional Agraria
UPoCA	Unleashing the Power of Cassava in Africa
USAID	United States Agency for International Development
WVG	World Vision Ghana
YIISFWA	Yam Improvement for Income and Food Security in West Africa
YMT	Yam minisett technique

Abstract

The seed systems of RTB (root, tuber, and banana) crops are unique because they are propagated from vegetative parts of the plant, not from true seed. RTB seed is thus bulkier, more perishable, and more subject to the attacks of pests and diseases than is true seed. Because of this, there is often a gap between potential and real crop yields, which seed interventions seek to narrow. Seed systems are formal or informal networks of people and organizations that produce, plant, and distribute seed. Informal systems may deliver low quality seed, but not always.

This book describes 13 RTB seed system interventions, using a framework based on the concepts of seed availability, access, and quality. The 13 case studies included (1) a potato-growers' association in Ecuador, (2) a hydroponic seed potato in Peru, (3) a yam seed technology in Nigeria, (4) a banana and plantain project in Ghana, (5) a sweetpotato seed project in Tanzania and (6) one in Rwanda, (7) a seed potato system in Kenya, (8) cassava in Nicaragua, (9) seed potato in Malawi, (10) disease-resistant cassava varieties in seven African countries, (11) a tissue culture banana project, (12) an emergency plantain and banana project in East Africa, and (13) a large cassava seed project in six African countries.

Good seed may be available, but farmers may not have access to it if delivery channels are poor, if the seed is too expensive, or if farmers do not know about it. Without an intervention (e.g., a project), seed is produced on-farm; shared among friends, neighbors, and family; and sold in local markets (i.e., in an informal system).

Some interventions try to organize farmers into new seed delivery channels. Some of these interventions succeed better than others. Seed can be distributed with vouchers, but that has a high administrative cost. Farmer organizations (or private companies) that are already well-structured may do a better job at distributing seed; but community nurseries can also be organized, especially if the goal is to distribute a new variety to farmers as a one-off, and not to create a permanent seed-supply enterprise.

Most of the interventions in this book had some information on farmer demand, but not necessarily a rigorous understanding of the seed system. In spite of this, most of the new seed met farmer demand. Most interventions worked with improved varieties, but seed interventions could favor native varieties. Genetic purity is easier to manage in RTB crops, which breed true (they are clones), but seed health must be carefully managed.

Market integration is important for developing a seed system. The seed can be made affordable by subsidies, for example, but farmers are more likely to buy seed if they can sell their harvests, or if they need a new variety to meet market demand (e.g., from a food manufacturer). The interventions described in this book did a fairly good job of linking stakeholders in mutually beneficial ways.



Projects seek to improve on informal systems. A farmer in Imo State, Nigeria, takes home cassava cuttings from the market.

Photo by Jeff Bentley

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Franklin Plasencia designed and drew the project area maps in chapters 2–14.

This book would not have been possible without the collaboration and innovative spirit of thousands of individual farmers, of whom far too few are mentioned in the text of this book.

Case Studies of Root, Tuber and Banana Seed Systems

Introduction

From “seed money,” to the “germ of an idea,” to the “seeds of change,” “seed” is a powerful metaphor, because seed is so common, so important, and because no matter how much we know about botany, it is still impressive to see a whole plant grow from a single grain. Most crops are grown from these sexually produced grains. Yet for some crops, ancient farmers found a way of avoiding the seed and planting some other part of the plant, like the root or the stem. Planting a root, a tuber, or a bit of stem was a way of cloning a plant, so the offspring would be just like the parent. Oddly enough, we have no one-word term for the non-seed organs of plants that are used to reproduce crops. We call them “planting material,” “vegetative seed,” or simply “seed.”

This book describes seed systems of RTB (root, tuber, and banana) crops, which are reproduced using vegetative plant parts, not by true seed resulting from pollination and fertilization. RTB crops often have a gap between real and potential yields, caused in part by losses to the pests and diseases which accumulate in successive cycles of vegetative propagation. True seed helps to eliminate many of these pests, and so grain and pulse crops have less of a yield gap than vegetatively reproduced plants. RTB crops are receiving much attention due to their significant contribution to world food production and income, especially for smallholders. Since about 2005, major donors have been substantially increasing investments in RTB seed systems, to disseminate new (improved) varieties and reduce the yield gap in existing ones (e.g., by improved crop and pest management). However, RTB seed systems are not always like those of grain and pulse crops, which have usually dominated the research and development agenda. RTB seed systems have suffered from low investments, weakly organized value chains, and poorly documented evidence of the value of interventions, among other shortcomings.

The main objective of this book, *Case Studies of Root, Tuber and Banana Seed Systems*, is to make suggestions for successful RTB seed system interventions by learning from previous experiences (case studies) and to highlight recommendations for the future. It was written for anyone who is interested in seed systems or RTB crops, including beginners and experienced researchers.

The chapters in this book include a description of RTB crops and principles of RTB seed systems (Chapter 1), then 13 case studies (Chapters 2–14, Table 1), and a cross-case analysis and discussion (Chapter 15). The case studies were selected to provide a wide variety of scale and types of interventions: some projects were in response to a crop disease emergency, while others intended to improve household (HH) nutrition, or to meet the new opportunities of developing markets. The case studies are organized from small-scale to large interventions, starting with three chapters on community-level projects (two with potato in the Andes, and one with yam in Nigeria). Chapters 5–9 describe cases involving several provinces within a country (sweetpotato in Tanzania and Rwanda, potatoes in Kenya, cassava in Nicaragua, and potatoes in Malawi). Chapters 10–12 discuss multi-country cases: cassava and banana in several African countries.

Table 1. Case studies

Chapter, Crop, and Country	Short name	Main focus
Chapter 2 Potato, Ecuador	CONPAPA (Consortium of Small Potato Producers)	A local farmers' organization produces quality declared potato seed for accessing high-value markets
Chapter 3 Potato, Peru	Cajamarca	Clean potato seed with funding from a mining company
Chapter 4 Yam, Nigeria	AYMT (Adapted Yam Miniset Technique)	Researchers improve an on-farm technique for planting more land with less seed yam
Chapter 5 Banana and plantain, Ghana	TARGET	Researchers shared new hybrids with farmers
Chapter 6 Sweetpotato, Tanzania	Marando Bora ("better vine")	Delivering local and improved varieties, producing clean seed off-farm, and managing vines on-farm for food security and nutrition
Chapter 7 Sweetpotato, Rwanda	Superfoods	Similar to the case above, with additional pull from a sweetpotato processor who requires a consistent supply of roots
Chapter 8 Potato, Kenya	Three generations (3G)	Disseminate new varieties and clean seed with rationalized regulations permitting quality declared seed
Chapter 9 Cassava, Nicaragua	CLAYUCA (Latin American & Caribbean Support for Cassava Research & Development)	New varieties for cassava awaken government and farmer interest after a lull of several years, in response to demand by agro-industry
Chapter 10 Potato, Malawi	Gender and seed	Men have better access to land and seed, but a new project fails both genders equally
Chapter 11 Cassava, West and Central Africa	UPoCA (Unleashing the Power of Cassava in Africa)	Disseminating new, disease-resistant varieties in seven countries
Chapter 12 Banana, East Africa	Tissue culture banana	Helping to establish nurseries where communities can harden tissue cultured bananas to sell to farmers
Chapter 13 Banana, East Africa	Emergency banana	A new multiplication technology and training to help farmers manage a new crop disease
Chapter 14 Cassava, East Africa	GLCI (Great Lakes Cassava Initiative)	A cassava initiative in the Great Lakes Region of Africa

The information in these case studies comes from project documents or from the authors' own experience. All of the authors met on several occasions in workshops to compare ideas. The 13 case

studies were based on interventions carried out by researchers, nongovernmental organizations (NGOs), and other practitioners in RTB seed systems between 1992 and 2015. The case studies represent work with thousands of farmers, in 14 countries, with five crops, with several partners each.

The case studies were analyzed using a slightly modified version of the multi-stakeholder framework for intervening in RTB seed systems (Sperling et al. 2013), which is an adaptation of the seed system security assessment (SSSA) developed by Tom Remington, Louis Sperling, and colleagues (Remington et al. 2002; Sperling 2008), based on an analogy with food security concepts (RTB 2016). The multi-stakeholder framework is a table-like matrix, which systematically considers stakeholders' perspectives in terms of seed availability, access, and quality (Table 2).

Table 2. Multi-stakeholder framework for intervening in RTB seed systems (see definitions in Chapter 1)

Stakeholder	Availability / supply	Accessibility			Quality	
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand	Variety (incl. biodiversity)	Health, genetic purity, physiological age, and physical quality ¹
Policymakers						
National research						
International research						
Traders (local markets)						
Specialized seed producers						
Farmer organizations						
NGOs & national extension						
Private food sector						
Seed users						
Others						

1 From Thomas-Sharma et al. (2015).

Each of the case studies is organized in a parallel format to follow the SSSA framework. The first two sections of each chapter describe the intervention and the general context. The third section is dedicated to the seed users, following seed availability, access, and quality. The fourth section describes the specialized seed producers, and the fifth one outlines the policy environment. The last section is on the rapid multiplication technique (RMT) (i.e., the technology itself). And although some editors might have put this section first, we wanted to emphasize the stakeholders of the seed system. Each of the case studies includes a summary table, based on the framework analysis.

CHAPTER I

Seed systems for roots, tubers, and bananas

By Jeffery Bentley,^a Jorge Andrade-Piedra,^b Conny Almekinders,^c Kim Jacobsen,^d Stephen Walsh,^c and Graham Thiele^b

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In this chapter we review some basic concepts about RTB crops and seed systems. The reader may be interested in other works on seed systems in general (Almekinders et al. 1994; Tripp 2001; Sperling and Cooper 2004; Sperling 2008); on seed systems in Africa (Van Mele et al. 2011); and on seed systems of the main RTB crops in developing countries: potato (Thiele 1999; Gildemacher et al. 2009; Struik and Wiersema 2012), cassava (Okechukwu et al. 2010; Walsh et al. 2010), sweetpotato (Barker et al. 2009; Gibson 2009; Namanda et al. 2011; Stathers et al. 2012; McEwan et al. 2015; McEwan 2016), banana and plantain (Staver et al. 2010; Jacobsen 2013), and yam (Coyne et al. 2010).

1. Vegetatively reproduced crops

Vegetatively reproduced crops include some with worldwide popularity such as bananas and potatoes, or of great regional significance such as cassava, sweetpotato, and yam. About 200 million smallholders in tropical countries grow RTBs. Because these crops are bulky and perishable, they are commonly grown for local consumption; however, large increases in production for RTBs and international trade (particularly between neighboring countries) have stimulated specialization in both crop and seed production and generated income and jobs. Smallholders often grow RTB crops within diverse cropping systems, increasingly integrated with output markets and used for agro-industry.

RTBs are major players in the global food system. In 2012, and considering the 20 top producers in each crop, the combined production of potato, cassava, sweetpotato, banana, plantain, and yam was nearly 819 million tons (MT)—that is, almost twice the amount of milled rice produced that year (486 MT) (FAOSTAT 2012). Potato had the highest production (288 MT), followed by cassava (245 MT), banana and plantain (125 MT), sweetpotato (102 MT), and yam (59 MT).

Banana, cassava, potato, sweetpotato, and yams are almost always planted from vegetative material. These RTB crops are managed in similar ways, especially in seed and postharvest. Women often grow these crops because they are important staple foods that contribute to food security. Some varieties of RTBs are rich in vitamins and minerals. RTBs like cassava are drought tolerant, while others

like banana and plantain protect against erosion and produce year round, thus bridging the hunger gap. RTBs are often a good rotation crop for cereals or complement with legumes for more efficient use of resources. RTBs build stronger, more resilient and diversified diets and farming systems which strengthen food security and reduce the global carbon footprint of food production systems (RTB 2015).

2. What is a seed system?

We define seed system as “the network of stakeholders (people, organizations, and companies) involved in producing and planting and selling the seed (including vegetative seed) of a particular crop in an arbitrarily defined geographical area (e.g., a province, a country, several countries).” The seed system is associated with certain agricultural and seed-production technologies, and with the genetic resources needed to produce the seed. Following Thiele (1999), the seed system can be formal or informal. Formal systems are regulated by the public sector, usually by the registration of the seed producer as an enterprise and an inspection process known as “certification” and controls over varieties used for multiplication, to ensure that available seed is of a recognized variety with a low incidence of disease. On the other hand, an informal seed system is managed by farmers themselves, without the public sector (ibid.). In this book, “seed system” includes the formal and the informal sectors, unless indicated otherwise.

The seed system loop can start and end with a single farmer (Almekinders et al. 1994), or it can be a large network articulated over a whole country (see Van Mele et al. 2011). A seed system could be defined from a project perspective (NGO, donor, host government, etc.), or a farmer perspective (self, community, agricultural extension services, and local traders).

Most seed systems for RTBs are local (seed is moved over short distances), due to the bulkiness and perishability of planting material. RTB seed systems include millions of farm families, some more integrated into the seed and commodities market than others. Most RTB planting material is produced and exchanged locally by farmers and their neighbors (McGuire and Sperling 2016). The informal seed markets are huge, and diverse, but they have often been ignored. Informal seed channels are increasingly being integrated with more formal seed channels, with breeding programs, seed health agencies, and specialist seed producers.

Seed system features

Improving availability, access, and quality of seed are the three main features of a seed system and are the basis for the seed security concept (Remington et al. 2002; Sperling 2008). Some definitions follow:

Availability of seed means that the planting material is present in the system, in enough quantity to supply farmers’ needs. Availability can mean that farmers produce their own seed, or source it from elsewhere. For RTB crops, availability means that a much greater volume of planting material must be present than for crops that use true seed.

Access means that farmers know where to get seed and can reach the delivery channel (e.g., the market, the NGO); farmers can afford the RTB planting material (which is bulkier and therefore more

expensive than true seed); and farmers have information about varietal characteristics of the seed and the advantages of clean seed.

Quality includes the varieties that farmers and consumers demand (and new varieties), and in good health, genetic purity (no mixtures), physiological age, and physical quality.

Seed systems stakeholders

Seed systems often include many stakeholders: farmers, input dealers, NGOs, international and national research centers, policymakers, and specialized seed producers, among others.

Policymakers (including seed certification and regulatory agencies) approve new crop varieties for release (and set the rules for doing so). They set the standards for trading plant materials in their own countries. Policymakers also set the agriculture, food security, and nutrition agendas which influence yield targets, priority crops, “growth areas,” target groups, and other topics which subsequently influence seed production. There is an increasing interest, shown in the following chapters, in harmonizing regulations across regions.

National governments and donors provide funds and decide where to invest (certification, plant breeding, training, etc.). Donors are especially important in countries where the host government may not be prepared to make these investments. This group is not always explicitly included in the framework, but someone has to finance a seed intervention, either a national government or a donor.

Researchers (national and international) produce almost all the new varieties. The plant breeders often work with farmers, often by using participatory plant breeding (Almekinders et al. 2014; Thiele et al. 2011, Chapter 3).

Traders (local markets) are especially important in the informal seed system. Seed traders may also deal in the ware product, depending on the season of the year. They move seed from farmers or regions that have it to seed users who need it. Seed traders may be unregulated, especially for RTB crops in tropical countries.

Farmer organizations can include specialized seed producers or seed users. They are important for helping to learn about demand for seed, and to share it with organized groups of farmers. Farmer organizations can be small, and village-based, or they can be national umbrella, member-based associations which bring together many grassroots groups.

Specialized seed producers may be private or public. They may also be farmers or organized groups of farmers who produce seed for their peers. They may use new technology such as aeroponics, tissue culture (TC), and other special technologies for producing seed. In the following chapters we see that multiplying vegetative seed may take three different types of stakeholders: a public agency to produce the foundation seed, a commercial company to multiply it with high technology, and a small farm or group of farmers to do a final, inexpensive multiplication for farmers in their community.

NGOs (national and international) and national extension agencies often do much of the actual on-the-ground implementation of seed system interventions. NGOs and extension agencies may

organize farmers and seed producers, distribute seed to seed users, document the project (monitoring and evaluation), and conduct training and extension with farmers.

Private food sector. Although they are not always part of the seed sector per se, large buyers of agricultural commodities, such as supermarkets and agro-industrial processors, often stipulate that farmers produce certain varieties (which may be new to the system). Sometimes the food processors take it upon themselves to produce seed, or at least to make sure that seed of their desired varieties is available.

The seed users, the farmers themselves, vastly outnumber all of the other stakeholders put together; yet their voices and their knowledge is the least acknowledged in the seed system. The farmers make the system work. They decide if they will use their own seed or venture to replace it. They decide which new varieties live or die. They manage the remaining biodiversity. They are women and men and youth.

3. Challenges

Vegetative seed has the advantage of allowing the crop to breed true-to-type. The stem cuttings, vines, roots, tubers, corms, suckers, and TC plantlets are clones, genetically identical to the parent plant. This can make these crops genetically uniform, but more susceptible to inheriting pathogens from parent plants. The incidence of pests (defined to include diseases—FAO 1996), especially viruses, makes vegetative seed more challenging to manage than true seed. The seed is highly perishable. Vegetative crops need many more kilograms of seed per hectare than do grains or pulses. For all these reasons, RTB seed systems are more localized than grain or legume seed systems.

Vegetative seed presents particular challenges because it:

- Is disease-prone
- Is bulky
- Has as a low multiplication ratio (each mother plant produces relatively little seed)
- Is perishable
- Is potentially expensive
- Is difficult to transport (and as a result, often produced locally).

Disease-prone. Pests and diseases, especially viruses, are more easily transmitted via vegetative planting material than through true seed. Some of these pests, like insects, nematodes, fungi, and bacteria, but especially viruses, can accumulate over time, reducing the yield and the quality of the crop (Table 1.1). This is called degeneration, and farmers often manage it by seeking new seed, planting varieties that degenerate slowly, or by using traditional practices to improve the health condition of the planting material. Degeneration can cause decreases in yield (e.g., caused by endemic viruses in potato). Emerging pathogens can also cause rapid and devastating losses, as in the case of bacterial Xanthomonas wilt (BXW) in banana.

Table 1.1. Key challenges of RTB planting material vs. a representative grain crop (maize)

Challenges	Maize	Banana	Cassava (2)	Potato	Sweetpotato (8)	Yam (9)
Degenerat. (main pests)	Seed degeneration is due to contamination by pollen from other varieties	Banana bunchy top virus, banana streak virus, banana bract mosaic virus; bacterial wilts caused by <i>Ralstonia</i> spp., and <i>Xanthomonas</i> sp.; <i>Fusarium</i> wilt; nematodes (<i>Radopholus similis</i> , <i>Pratylenchus</i> spp., <i>Helicotylenchus</i> spp., <i>Meloidogyne</i> spp., <i>Hoplolaimus</i> spp. and weevils (<i>Cosmopolites sordidus</i>)	Cassava mosaic viruses, cassava brown streak viruses, cassava frogskin-associated viruses; bacterial blights (<i>Xanthomonas campestris</i> pv <i>manihotis</i>); cassava green mite and mealy bugs	Potato virus (PVX), PVY, potato leafroll virus, <i>Ralstonia</i> , <i>Rhizoctonia</i> , <i>Pectobacterium</i> , <i>Spongospora</i> , <i>Globodera</i> , <i>Meloidogyne</i> , <i>Tecia</i> , <i>Symmetrischema</i> , <i>Phthorimaea</i> , etc. (3)	Sweet potato virus disease: a complex arising from interaction between sweetpotato chlorotic stunt virus and sweetpotato feathery mottle virus transmitted by whitefly and aphids	Viruses: yam mosaic virus, yam mild mosaic virus; nematodes: <i>Scutellonema bradys</i> , <i>Meloidogyne</i> spp.; fungi: <i>Botryodiplodia</i> sp., <i>Fusarium</i> sp.; insects: termites (<i>Amitermes</i> sp.), tuber moth (<i>Euzopherodes vapidella</i>), etc. (10)
Bulkiness	20 kg/ha (1)	1,000–2,500 kg/ha (for traditional suckers)	Usually 10,000 three-node stem cuttings (about 15 cm long) per ha	1,000–2,000 kg/ha	About 33,300 cuttings (25–30 cm), or about 666 kg depending on variety & stage of wilting	Usually 10,000 tubers or minisetts of ~100–300 g/ha (at traditional spacing of 1 x 1 m ²)
Multiplicat. ratio	1:100	1:10–1:20 suckers	1 ha yields about 200,000 stems (8–12 stakes from 1 plant)	1:20 tubers (4)	A vine may yield 2 or 3 cuttings 30 cm long	1:8 tubers
Storability of harvested seed	Up to 1 year	2–3 weeks depending on the season	2 to 3 weeks maximum	Up to 6 months	A maximum of 2–3 days	3–4 months
Seed cost (\$/ha)	\$16–\$27*	\$32–\$2,240, but usually free as farmers would provide their own	\$60–\$120	Up to 50–70% of total production cost (3). \$2,527/ha (Chile, 5); \$818/ha (Idaho, 6); \$1,090/ha (Peru, 7)	Highly variable. For Tanzania a \$2 bundle of 300 vines makes 3 cuttings each, or 900 cuttings. Circa \$76/ha	About \$500–\$800

- (1) \$0.80–\$1.00/kg for open-pollinated subsidized maize in Nigeria, \$1.33/kg for private sector hybrid (Bentley et al. 2011). Certified maize seed is sold for roughly the same price in Peru, according to the INIA website www.inia.gob.pe/prod-servicios/semillas
- (2) IYA (2014)
- (3) Thomas-Sharma et al. (2015)
- (4) Struik and Wiersema (1999)
- (5) Ministerio de Agricultura (2013). 1 USD = 554 Chilean pesos
- (6) Patterson (2014)
- (7) Victor Suárez (pers. comm.). Varieties ‘Canchán’ and ‘Yungay’ in Julcán province, La Libertad department in 2013. 1 USD = 2.75 Peruvian Sol.
- (8) Kwame Ogero (pers. comm.)
- (9) Ibane (2011)
- (10) Emehute et al. 1998.

One frequently suggested solution to manage degeneration, for potato in particular, is the use of clean seed, ideally produced by a formal system. But this has had limited success with smallholders in developing countries. Another approach that is being put into practice is to use resistant varieties and improve the quantity of seed produced and managed by farmer multipliers at the community level.

The use of certified seed in RTB crops is often low, and in many crops and countries there is little use of quality standards for RTB planting material. Challenges include the lack of institutional capacity, the lack of implementation mechanism, and in some cases inappropriate standards.

Bulky. It takes much more seed (in terms of weight) to plant 1 ha of RTBs than to sow a grain crop (Table 1.1). This raises transaction, transportation and storage costs. Bulky, vegetative seed is more difficult to distribute than true seed.

Low multiplication ratio. Because vegetative seed is bulky, it is slow to reproduce by conventional methods and has a low ratio of seed-to-harvest, making the total seed requirement expensive (Table 1.1).

Perishable. Most grain seeds can be stored for a year on-farm. The cuttings, roots, and tubers of vegetative seed are nearly as perishable as fresh fruits and vegetables. Sweetpotato vines (seed), for example, are as short-lived as lettuce (Table 1.1).

Expensive. Vegetative seed can be expensive (Table 1.1). Potato seed may be half the production cost of growing the crop. By contrast, seed is just a small fraction of the production cost for maize.

As a result of all of the above, in informal systems in developing countries, most RTB seed is produced locally. Farmers save some planting material and buy some from local fairs, unregulated markets, neighbors, or through their networks of gifts and barter. As the planting material is recycled from the previous seasons, it can lead to degeneration. The seeds may carry disease, even if they look healthy. Also, in informal systems, farmers may have limited access to outside sources of seed (e.g., new varieties to respond to new market opportunities), or to replace seed of existing varieties lost during emergencies.

Even when seed is available on the market, smallholders in the tropics may often prefer using their own seed to save money and because some of these crops are risky to grow (weather, pests, erratic market prices). It may not be profitable to invest in seed if there is no market that pays for high quality or better yields. Markets are not just places where farmers buy and sell their seed. Markets for the ware produce can also stimulate farmers to buy seed.

4. Conclusions

Seed systems are complex: they include both seed flows and use, and a linked set of actors. If a successful seed system intervention is to achieve sustainable change, it will require coordinated action by multiple actors. The social network to support a clonally propagated seed system is especially complex because of the bulkiness and perishability of the seed, and the need to decentralize seed production near growers and concerns around degeneration. So many more actors are necessarily involved than in a system for true seed.

The actors often tug in different directions, with regulatory authorities insisting on protocols of seed inspection which seed multipliers cannot actually afford. Others generate varieties not responding to what farmers actually need. One essential step is to lay out the actors and their roles in determining seed security. This can help understand the seed system and indicate key points for improving actor coordination. So while many of the problems of RTB seed are “technical,” the solutions have to be “social” as well.

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References cited

- Almekinders CJM, Louwers NP, De Bruijn GH. 1994. Local seed system and their importance for an improved seed supply in developing countries. *Euphytica* 78:207–216.
- Almekinders CJM, Mertens L, van Loon JP, Lammerts van Bueren ET. 2014. Potato breeding in the Netherlands: a successful participatory model with collaboration between farmers and commercial breeders. *Food Security* 6:515–524.
- Barker I, Andrade M, Labarta R, Mwanga R, Kapinga R, Fuentes S, Low J, eds. 2009. Sustainable Seed Systems. Challenge Theme Paper 2. Unleashing the potential of sweetpotato in Sub-Saharan Africa: Current challenges and way forward. Lima: CIP.
- Bentley JW, Tripp R, Delgado de la Flor R. 2001. Liberalization of Peru’s Formal Seed Sector. *Agriculture and Human Values* 18(3):319–331.
- Coyne D, Claudius-Cole A, Kikuno H. 2010. SP-IPM Technical Innovation Brief 7. Sowing the seeds of better yam. IITA, Nigeria. (Available from www.spipm.cgiar.org/c/document_library/get_file?p_l_id=17830&folderId=18484&name=DLE-1360.pdf)

- Emehute JKU, Ikotun T, Nwauzor EC, Nwokocha HN. 1998. Crop protection. In: Orkwor GC, Asiedu R, Ekanayake IJ, eds. *Food Yams: Advances in Research*. Ibadan: IITA. p. 141–186.
- FAO. 1996. Glossary of phytosanitary terms. (Available from www.fao.org/docrep/w3587e/w3587e01.htm)
- FAOSTAT. Food and Agriculture Organization of The United Nations. <http://faostat.fao.org/>
- Gibson RW. 2009. Review of sweetpotato seed systems in East and Southern Africa. Working Paper 2009-1. Lima, Peru: CIP.
- Gildemacher PR, Demo P, Barker I, Kaguongo W, Woldegiorgis G, Wagoire WW, Wakahiu M, Leeuwis C, Struik PC. 2009. A Description of Seed Potato Systems in Kenya, Uganda and Ethiopia. *American Journal of Potato Research* 86:373–82.
- Ibana S, Coyne D, Claudius-Cole A, McNamara N, Morse S. 2011. Economic analysis of commercial seed yam production systems in the sub-humid ecologies of the River Niger. *Journal of Crop Improvement* 26:1–17.
- [IYA] IITA Youth Entrepreneurs. 2014. Cassava value chain members—Rapid multiplication of cassava stems. Ibadan: IITA. 9 pp.
- Jacobsen K. 2013. Review of seed systems for bananas and plantains (*Musa* spp.). Working paper for the Seed Systems Working Group of Roots, Tubers and Bananas. 56 pp.
- McEwan M, Almekinders C, Abidin PE, Andrade M, Carey EE, Gibson RW, Naico A, Namanda S, Schulz S. 2015. Can small still be beautiful? Moving local sweetpotato seed systems to scale in Sub-Saharan Africa. In: Low J, Nyongesa M, Quinn S, Parker M, eds. *Potato and Sweetpotato in Africa Transforming the Value Chains for Food and Nutrition Security*. Wallingford, UK: CABI.
- 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. CGIAR Research Program on Roots, Tubers and Bananas (RTB), Lima. RTB Working Paper No. 2016-4. ISSN 2309-6586. 55 p.
- McGuire S, Sperling L. 2016. Seed systems smallholder farmers use. *Food Security* 8:179–195.
- Ministerio de Agricultura de Chile. 2013. Ficha técnica-económica, papa guarda, región del Biobío.
- Namanda S, Gibson RW, Sindi K. 2011. Sweetpotato seed systems in Uganda, Tanzania, and Rwanda. *Journal of Sustainable Agriculture* 35(8):870–884.
- Okechukwu RU, James B, Ntawuruhunga P, Mahungu N, Boahen S, Kanju E, Osei-sarfoh A. 2010. Distribution and Potential Impact of Cassava Variety Spread by UPoCA. In: Okechukwu RU, Ntawuruhunga P, eds. *Proceedings of the 11th Triennial Symposium ISTRC-AB*. p. 325–328.
- Patterson P. 2014. Cost of potato production for Idaho with Comparisons to 2013. Moscow, ID: University of Idaho. 30 p.
- Remington T, Maroko J, Walsh S, Omanga P, Charles E. 2002. Getting off the seeds-and-tools treadmill with CRS seed vouchers and fairs. *Disasters* 26(4):316–328.

- RTB. 2015. "Background." (Available from www.rtb.cgiar.org)
- RTB (CGIAR Research Program on Roots, Tubers and Bananas). 2016. Multi-stakeholder framework for intervening in RTB seed systems. RTB Working Paper No. 2016-1. ISSN 2309-6586. 13 p.
- Sillitoe P. 2010. *From Land to Mouth: The Agricultural "Economy" of the Wola of the New Guinea Highlands*. New Haven: Yale University Press. 573 pp.
- Sperling L. 2008. *When disaster strikes: A guide for assessing seed security*. Cali: CIAT.
- Sperling L, Cooper HD. 2004. Understanding seed systems and strengthening seed security: A background paper. In: Sperling L, Osborn T, Cooper D, eds. *Towards Effective and Sustainable Seed Relief Activities*. p. 7–33. Rome: FAO Plant Production and Protection Paper 181. Report of the Workshop on Effective and Sustainable Seed Relief Activities, 26–28 May 2003.
- Sperling L, Ortiz O, Thiele G. 2013. RTB seed systems: Conceptual frameworks for guiding practical interventions. Draft 1—RTB Working Paper 2013-1. Lima: CGIAR Research Program on Roots, Tubers and Bananas.
- Stathers T, Low J, Mwanga R, Carey T, David S, Gibson R. 2012. *Everything You Ever Wanted To Know About Sweetpotato: Reaching Agents of Change ToT Manual*. Nairobi, Kenya: CIP.
- Staver C, van den Bergh I, Karamura E, Blomme G, Lescot T. 2010. Targeting actions to improve the quality of farmer planting material in bananas and plantains: Building a national priority-setting framework. In: Tripathi L, ed. *Bananas, plantains and enset*. Tree and Forestry Science and Biotechnology 4 (special issue): 1–10.
- Struik PC, Wiersema SG. 1999/2012. *Seed Potato Technology*. Wageningen, The Netherlands: Wageningen Academic Publishers.
- Thiele G. 1999. Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27(1):83–99.
- Thiele G, Devaux A, Reinoso R, Pico H, Montesdeoca F, Pumisacho M, Andrade-Piedra J, Velasco C, Flores P, Esprella R, Thomann A, Manrique K, Horton D. 2011. Multi-stakeholder platforms for linking small farmers to value chains: Evidence from the Andes. *International Journal of Agricultural Sustainability* 9:423–433.
- Thiele G, Quirós CA, Ashby J, Hareau G, Rotondo E, López G, Paz Ybarnegaray R, Oros R, Arévalo D, Bentley J, eds. 2011. *Métodos participativos para la inclusión de los pequeños productores rurales en la innovación agropecuaria: Experiencias y alcances en la región andina 2007–2010*. Programa Alianza Cambio Andino. Lima: CIP. 197 pp.
- Thomas-Sharma S, Abdurahman A, Ali S, Andrade-Piedra JL, Bao S, Charkowskif AO, Crook D, Kadian M, Kromann P, Struik PC, Torrance L, Garrett KA, Forbes GA. 2015. Seed degeneration in potato: The need for an integrated seed health strategy to mitigate the problem in developing countries. *Plant Pathology* 65:3–16.

Tripp R. 2001. *Seed Provision & Agricultural Development: The Institutions of Rural Change*. London: Overseas Development Institute. 174 pp.

Van Mele P, Bentley JW, Guéi R. 2011. *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford, UK: CABI. 236 pp.

Walsh S, Phemba P, Onyango-Odero B, Marandu E. 2010. Seed system innovations in the Great Lakes Cassava Initiative. Proceedings of the 11th ISTRC-AB Symposium held in Kinshasa, DR Congo, 4–8 October 2010. p. 354–361.

CHAPTER 2

Integrating formal and informal potato seed systems in Ecuador

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Abstract

CONPAPA is a farmers' organization in Ecuador established to connect smallholders to their buyers and to consumers in the cities. These new links, and an expanding market for potatoes to supply the cities, allowed farmers to sell better potatoes at higher prices. This in turn allowed farmers to buy seed, although they could not always afford certified seed, which was often in short supply. Smallholders in CONPAPA organized themselves to buy high-quality source seed potato from Ecuador's National Agricultural Research Institute (INIAP), plant it, and produce their own quality declared seed, which they sell to members and non-members alike. To become a seed producer, farmers must apply to CONPAPA. Candidates then receive training and collaborate in quality control visits. Quality control is best exercised as a teaching exercise (not like a visit from the police) that helps to find problems and counsels farmers on how to manage them in the future. CONPAPA's experience with seed has influenced the Ministry of Agriculture (MoA) in Ecuador to change the quality control guidelines used for certified seed, and include parameters developed by INIAP and CONPAPA, with support from the International Potato Center, for a seed category equivalent to quality declared seed as part of the legal seed system.

Rationale

Operate a sustainable potato seed system for smallholder farmers that will allow them to produce potatoes for high-value markets. The CONPAPA seed producers receive quality source seed from the formal system, and multiply it as quality declared seed (QDS) (FAO 2006; Fajardo et al. 2010) that is of good quality but is less expensive than certified seed. The seed producers sell this seed to other members of the CONPAPA farmers' consortium, at a volume, price, quality, and time that allows them to produce ware potatoes that meet the requirements of a high-paying market, such as supermarkets and restaurants.

1. The intervention

1.1 BACKGROUND, ACTIVITIES, SCALE AND SCOPE, AND THEORY OF CHANGE

Beginning in 2001, the FORTIPAPA project (Spanish for Strengthening of Research and Production of Potato Seed), financed by the Swiss Agency for Development and Cooperation and Ecuador's (INIAP) potato program with support from CIP's Papa Andina project, arranged for a dynamic series of meetings and visits between farmers and other stakeholders in the potato value chain, and applied the so-called participatory market chain approach (Devaux et al. 2009) to generate innovations. As a result, several multi-stakeholder platforms were created to improve the position of small-scale potato farmers in local potato business.

The multi-stakeholder platforms are alliances between smallholder farmers and various agricultural service providers and potato clients. The multi-stakeholder platforms link farmers to high-value markets, which reduce the transaction costs of buying small volumes from many farmers. The platforms give smallholders the information they need to produce potatoes that meet the requirements of restaurants, supermarkets, and processors who are willing to pay a premium for higher grade potatoes (Cavatassi et al. 2011). This empowered farmers and led to the creation of CONPAPA and a business that produced, planned, invested in, and marketed high-value niche potato in 2005 (Thiele et al. 2011). CONPAPA based its potato production on high-quality source seed; however, it soon became obvious that the formal seed system could not deliver enough quality source seed due to a lack of staff and institutional weaknesses.

CONPAPA has offices in the provinces of Tungurahua, Chimborazo, and Bolívar, each with its own independent legal status, provincial board, local seed system, and management office with hired staff that organizes production). About 500 smallholders are members of CONPAPA (50–70 in Tungurahua and the rest in Chimborazo and Bolívar). Typically, members own around 3 ha of land and cultivate potatoes on 1 ha; most farms are located above 3,000 masl. The CONPAPA seed system is similar in the three provinces, although there are some peculiarities among them. The experience in Chimborazo and Bolívar is different: in those two provinces farmers are more involved in producing certified seed. The semi-formal system described here is from Tungurahua.



The theory of change was to respond to CONPAPA's seed demand by starting a semi-formal seed system (part formal and part informal) to be run by CONPAPA, and to secure the local supply of quality seed that would allow CONPAPA to link to a high-value ware potato market, thereby providing income to farmers and access to new potato-growing technologies. INIAP's potato program started the CONPAPA seed system with support from CIP, based on an established farmers' organization, a clear market-orientation, support from local partners, and delivery of high-quality source seed from the formal potato seed system. Trained farmers multiply high-quality source seed of a variety with market demand, following an internal quality control procedure supervised by the consortium, a process that is similar to QDS (FAO 2006; Fajardo et al. 2010).

CONPAPA sells this seed to potato growers, who plant it to produce ware potato for market niches (Figure 2.1). CONPAPA staff help the members with marketing by organizing sales to a list of ware potato clients.

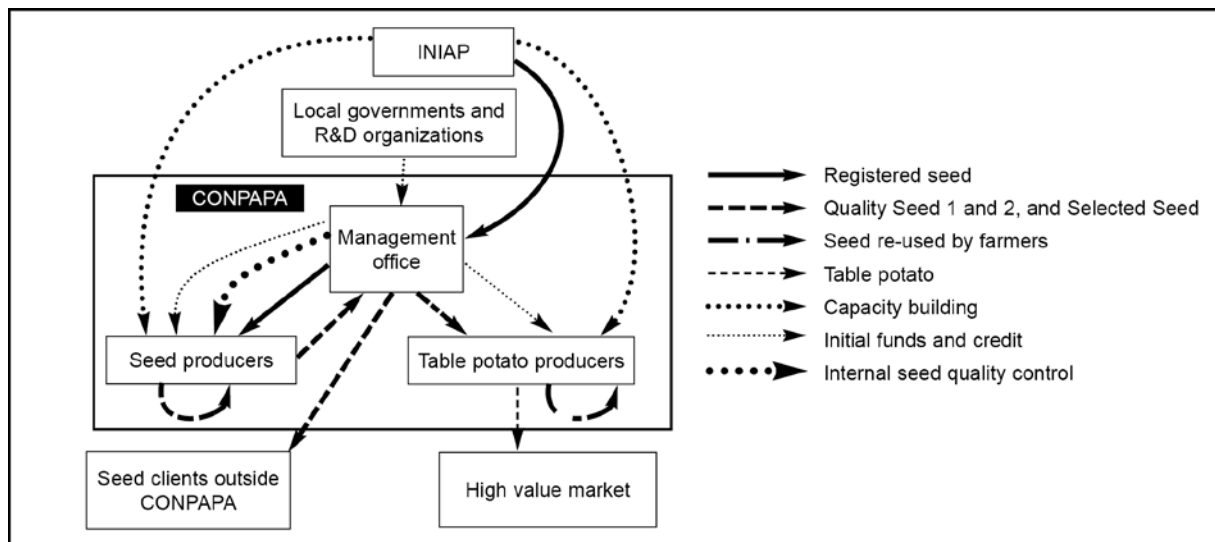


Figure 2.1. The CONPAPA seed system in Tungurahua.

1.2 UP-SCALING PERSPECTIVES, ACHIEVED OBJECTIVES, IMPACT

Besides selling seed potato to its member farmers, the CONPAPA seed system also provides seed to others, such as NGOs, government programs, and individual farmers. CONPAPA farmers produce an impressive 18 kg of seed for each kilogram they get from the formal system, which is achieved by replanting some of the source seed in successive cycles of propagation. Farmers have been trained in the benefits of using high-quality seed and are willing to pay for the quality seed needed to supply high-value ware potato markets—mainly fast-food restaurants and supermarkets. CONPAPA farmers on average obtained 33% higher yields than their non-participating neighbors (Cavatassi et al. 2011). Part of this yield increase can be attributed to CONPAPA seed. Hibon (2008) reports that consortium members sometimes earn a rate of return of 50% on CONPAPA seed, and that the farm-gate price for CONPAPA ware potatoes from 2004 to 2008 was 14–70% higher than those on the local market. Good seed and

access to upscale markets allowed CONPAPA farmers to reap profits about four times higher than comparative farmers' groups (FGs) (Cavatassi et al. 2011).

CONPAPA seed is produced with the consortium's internal quality control procedures. The improved seed quality helps ensure that the consortium's ware potatoes are of the quality required by the high-value, niche ware potato markets. The sales of CONPAPA seed to non-members, and even some cases of falsified CONPAPA seed, show that potato farmers see the value of CONPAPA seed. The consortium's seed system and planting programs continuously provide seed on time to ware potato producers. The successful diffusion of new potato varieties in the central highlands of Ecuador can be attributed mainly to CONPAPA. The multi-stakeholder platform and CONPAPA helped link smallholders to the new agricultural economy and increase their income (Cavatassi et al. 2011; Hibon 2008; Thiele et al. 2011).

The CONPAPA farmer consortium was built largely on the basis of its quality seed. CONPAPA is a platform for rural learning, empowering more than 1,000 families by 2008 (Hibon 2008). The CONPAPA farmers are now more visible in society, with improved livelihoods and increased self-esteem (ibid.). Although CONPAPA only has 500 members, perhaps 10 times that many families have benefited from the dissemination of new technologies and improved varieties. In 2012, a ministerial agreement was issued that established new protocols for producing certified seed, founded on the protocols used by CONPAPA.

Ecuador's national government has recently invested money in economic and social development, including the seed potato sector, coupled with special support to CONPAPA, linking it to the new agricultural development in the country. CONPAPA Tungurahua maintains its principal support from the local provincial government. CONPAPA in Bolívar receives considerable funding from international cooperation, and CONPAPA in Chimborazo has captured funding from the MoA, including \$150,000 to build a potato storage facility. The continuing growth of urban markets, especially the expanding demand for fine potatoes for supermarkets, means that the experience has room for scaling up.

Framework: Potatoes in Ecuador

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Polymakers			Allowed farmers to produce QDS			Used quality criteria from CONPAPA to set new seed standards
National research	Develops & releases varieties Provides certified seed	Fortipapa, project forged links between actors				
International research				CIP supported multi- stakeholder platforms	CIP facilitated policy change for QDS	
Traders (local markets)						
Private seed sector						
Farmer organization (CONPAPA)	Set production plans of QDS	Bought certified seed. Organized sales of QDS to farmers	QDS lowered price of seed	Promoted commercial varieties (e.g., by farmer field schools)	CONPAPA provided quality control	Made standards more realistic
NGOs		NGOs* bought seed from CONPAPA		PMCA helped share info between actors		
Private sector processors				Supermarkets & restaurants stimulated demand for constant supply	Supermarke ts & restaurants stimulated demand for varieties	Supermarkets demanded quality (e.g., size, health)
Seed users			Women, indigenous farmers could afford QDS seed		Demanded the varieties offered**	Demanded high- quality seed

* To distribute to other farmers. Local NGOs included Central Ecuatoriana de Servicios Agropecuarios, Minga para la Acción Rural y la Cooperación, and the Instituto de Ecología y Desarrollo de las Comunidades Andinas.

**Especially highly commercial, modern ones like 'INIAP-Fripapa' and 'Superchola'. Previously, the certified seed system had provided them, but not enough to meet demand, and not targeting smallholders.

2. General context

2.1 POTATO FARMING SYSTEMS IN ECUADOR

For millennia, potato (*Solanum* spp.) has been the main staple food in the Andean highlands, with Ecuadorian farmers developing hundreds or thousands of native varieties. But since the 1970s, native potatoes have lost importance in urban markets and have been almost entirely replaced by new varieties introduced by the national breeding programs. Ecuador is rapidly urbanizing, and agriculture is increasingly integrated into the urban market; however, smallholder farmers have been largely excluded from the urban markets.

Potatoes can be grown year-round in highland Ecuador. Farming is by hand, with diverse agro-niches, various technologies, and uneven yields. Most potatoes are grown on a small scale: 75% of the Ecuadorian potato farmers have fewer than 5 ha and 30% have fewer than 1 ha. However, larger producers supply more than 50% of the national potato supply (Devaux et al. 2010). Smallholders tend to be unorganized, with limited access to information (such as markets) and technology (e.g., quality seed and irrigation), and are farming in remote areas far from urban markets. Many farmers use modern technology sparingly, and receive prices that make it hard to pay for quality seed, irrigation, fertilizer, and pest management technologies, especially because it is difficult to get loans. Frost, hail, and drought, all too common in the high mountains, make potato farming a risky business.

2.2 MARKET IMPORTANCE OF POTATO

Most of the potato produced in Ecuador is still boiled at home, where it is a staple for rural and urban families. The potato processing industry is still in its infancy, handling only 10% of the national production (Devaux et al. 2010). The multinational company Frito-Lay is the only established large processor. Most potatoes are processed by small companies, mostly informal ones that supply Ecuadorian fast-food restaurants. Almost no potatoes are exported. Legal import is mostly of pre-fried, frozen French fries for multinational fast-food restaurants, but there is still illegal import of some fresh potatoes smuggled over the borders from Colombia and Peru. Ecuador is basically self-sufficient in potatoes and does not sell on the international market or compete much with neighboring countries (because of the varieties produced, low yields, high transport costs, and the risk of crossing borders with perishable goods).

The potato market lacks production planning and suffers from low public and private investment in seed quality and in postharvest infrastructure, although investment has increased in recent years. The potato market lacks mass information systems, such as broadcasting daily prices on the internet or radio, and has relatively high production costs. Smallholders are unorganized and, with only a few large wholesalers, are in a weak bargaining position. Consequently, potato prices fluctuate during the year and there is a hefty price margin between the producer and the consumer. Ecuador has a limited range of potato products, with a few varieties (especially 'Superchola') dominating both the fresh and the processing markets. There is little storage, so the price of ware potato changes with the weekly supply. Ware potato prices are volatile, although they normally peak in October and November, which is the main potato-planting time.

2.3 GENERAL POTATO SEED SECTOR CHARACTERISTICS IN ECUADOR

The national average potato yield is increasing, but is still low at 8.3 t/ha (FAOSTAT 2012). Yields are higher in neighboring Peru (14.3 t/ha) and Colombia (18.2 t/ha). The low yields in Ecuador are mainly due to marginal soils in mountainous areas prone to frost and drought, and the limited use of new technology, such as fertilizer, irrigation, and quality seed. Most potato farmers use informal seed either from their previous harvests or from neighbors or local markets.

2.4 TRENDS, DEVELOPMENTS, ONGOING CHANGE OF CONTEXT

The current government is trying to launch policies that will help small-scale agriculture, and there have been several recent ministerial initiatives to improve farmers' access to quality seeds. Ministerial agreements issued in 2012 and 2013 established new protocols for producing certified seed and an emergency seed category, which was transformed to be similar to QDS, called "semilla común," using parameters and experiences from CONPAPA. In addition, CONPAPA in Chimborazo received funding from the MoA to build a large potato storage facility. The formal seed system has been improved with renewed funding for certification and for salaries. The MoA has invested in a large greenhouse to produce more high-quality source seed through hydroponics and aeroponics in order to supply certified potato seed to most of the country's commercial potato producers.

The MoA has also implemented programs to broadcast daily prices of agricultural commodities on the internet, and to control contraband potato coming in from neighboring countries. The private sector is also investing in small-scale farming. It is becoming increasingly common for large agrochemical companies to extend credit to smallholders, who are also being aided by governmental insurance programs. Supermarkets are buying more and more food. The migration of many rural people to the cities, coupled with increasing wages, has raised the cost of farm labor. Small farms are increasingly being taken over by neighbors and bigger farms with links to urban markets. In this new environment, more farmers are now able to pay more for seed produced off farm.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *The situation before the intervention*

Before the creation of CONPAPA, small-scale potato farmers lacked access to certified seed. Occasionally, a few FGs received certified potato seed from research and development projects or political programs; but in general certified seed was only available to large-scale farmers, near the certified seed farms around the capital city of Quito. Some farmers bought certified seed if they had personal contacts with certified seed growers. Indigenous and women farmers living in remote places were further excluded from certified seed because of their poverty, gender, location, and ethnicity.

Yet over the years, the sporadic, decentralized supply of certified seed to smallholders and the centralized supply to large-scale growers generated a certain awareness of the term "certified seed" among farmers, particularly large-scale ones. Before the intervention, the current CONPAPA potato farmers used informal seed from their previous harvests or from neighbors or local markets. Such seed

was, and still is, usually traded at a lower price than even the common ware potato, because farmers had a low appreciation of this seed, and because it is produced as a by-product of growing ware potatoes. Only a few towns had informal potato seed depots where seed was sold for more than ware potato. The demand for certified potato seed was low among Ecuadorian farmers before CONPAPA. It has been estimated that less than 0.5% of the potato farmers in Ecuador received seed from the formal seed system (CNA 2002).

Farmers knew little about managing seed potato. The outreach of previous potato seed programs was limited and included practically no information on how to use the seed and what benefits to expect. Previous programs had, however, disseminated the “diffused light storage (DLS)” technique (a shed with shelves to keep potatoes shaded from direct sunlight) and some other seed management techniques, such as leaving the recently harvested seed tubers in direct sunlight to control pests and diseases. The vast majority of farmers selected seed tubers from their previous ware potato harvest, choosing the smaller tubers to plant, with little attention to healthy and vigorous tubers. Tubers that could not be sold as ware potatoes were used as seed. It was common practice to plant two or three small tubers together to compensate for their poor quality. If farmers realized that their own seed was becoming “tired” (degenerated), they would obtain seed from other farmers or local markets. But the most common reason for acquiring new seed was the loss of one’s own seed before or after harvest because of weather, pests, or disease.

The institutions that started CONPAPA knew about the low use and the appreciation and knowledge of quality seed. They identified the high-value niche market for quality ware potato as a driver to create the seed system.

3.1.2 What changed as a result of the intervention

The intervention linked farmers to new market niches, which are still the main drivers of the decentralized CONPAPA seed system. The system supplies farmers with quality seed of varieties (‘INIAP-Fripapa’, ‘Superchola’, and others) demanded by high-value markets, at a volume, price, quality, and time that allow ware potato producers of the consortium (and some non-members) to continuously deliver good tubers on time. This seed helped farmers in CONPAPA/Tungurahua sell 4,004 t of high-quality ware potato to discriminating markets between 2005 and 2010 (Table 2.1)



Tubers of ‘INIAP-Fripapa’, a variety suitable for French fries and for eating boiled or baked.

Photo by Jorge Rivadeneyra

Table 2.1. Volume and prices of potato seed produced by CONPAPA/Tungurahua from 2005 to 2010

Year	Source seed from INIAP				Quality seed produced by CONPAPA				Ware potatoes	
	Bought from INIAP		Sold to seed producers		Bought from seed producers		Sold to farmers, etc.		Sold to restaurants	Farm gate price ^a
	t	\$/kg	t	\$/kg	t	\$/kg	t	\$/kg	t	\$/kg
2005	5.6	0.43	5.2	0.45	48.0 ^b	0.24	42.7	0.27	168.2	0.23
2006			0.4	0.50	58.3	0.26	66.6	0.29	834.3	0.24
2007	2.6		2.6	0.45	80.1	0.26	107.5	0.27	935.9	0.19
2008	13.7	0.50	13.7	0.50	127.4	0.32	79.3	0.39	721.4	0.37
2009	9.9 ^c	0.66	1.5	0.68	179.7	0.35	145.4	0.47	699.8	0.32
2010	1.4	0.66	3.9	0.70	122.8	0.30	96.9	0.42	644.2	0.28
Total	29.9		26.9		616.3		538.4 ^d		4003.8	

All prices are in US Dollars.

a Ware potatoes are sold to restaurants for prices that are 6% higher to cover transaction costs.

b Bought from external seed producers.

c Plus 10,000 pre-basic minitubers from INIAP.

d Varieties 'INIAP-Fripapa'—70%; 'Superchola'—20%; and others included 'ICA-Única', 'Diacol-Capiro', and 'INIAP-Natividad'.

Volume. From 2005 to 2010 CONPAPA/Tungurahua had a steady increase in production and sold 539 t of quality seed (Table 2.1). This volume was produced on an average of 25 seed lots of at least 0.5 ha/ year and was produced from approximately 29.9 t of source seed bought from INIAP. This indicates a multiplication rate of source seed to high-quality farmer-produced seed of approximately 18:1, which is achieved by replanting some of the source seed over again.

Timely provision. The consortium's seed system has provided seed to its ware potato producers year-round (see Figure 2.2 for typical volumes).

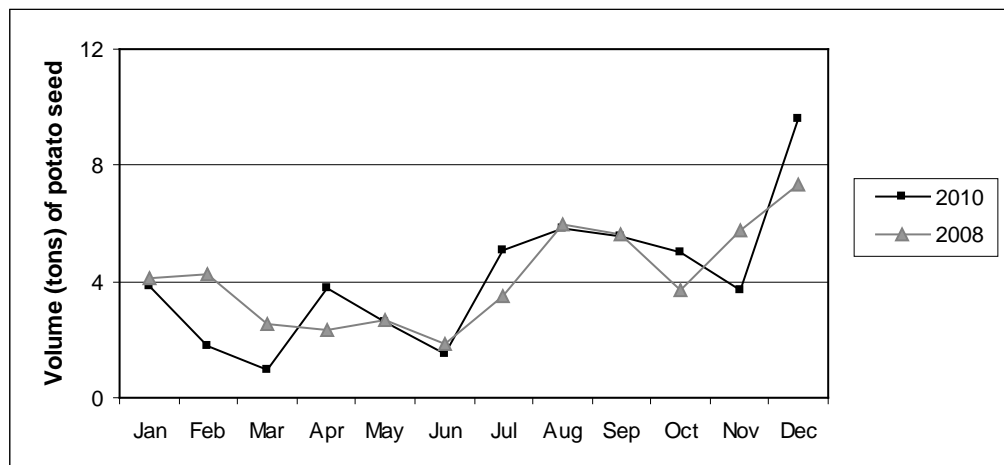


Figure 2.2. Monthly volumes of CONPAPA seed planted by ware potato producers in CONPAPA/Tungurahua in 2008 and 2010.

Distribution channels. CONPAPA seed was decentralized, produced by local farmers for local farmers, which helped to avoid social barriers and to ease logistical difficulties and to foster cooperation and trust between seed producers and users. Thanks to the improved distribution channels, women and indigenous members of CONPAPA now had quality seed derived from TC for the first time.

3.2 AFFORDABILITY OF THE “NEW SEED”

The price of CONPAPA/Tungurahua seed sold to farmers has risen over the years from US \$0.28/kg before 2008 to around \$0.43/kg after 2008 (Table 2.1). After 2008 the price difference between ware potato (farm-gate price) and seed potato (sold to farmers) has been noticeably larger than before 2008 (Table 2.1; Figure 2.3), indicating that farmers can now afford the seed and appreciate its value. Consequently, since 2008 the monthly price fluctuations for seed potato have been stabilized compared with the large fluctuations in ware potato prices (Figure 2.3).

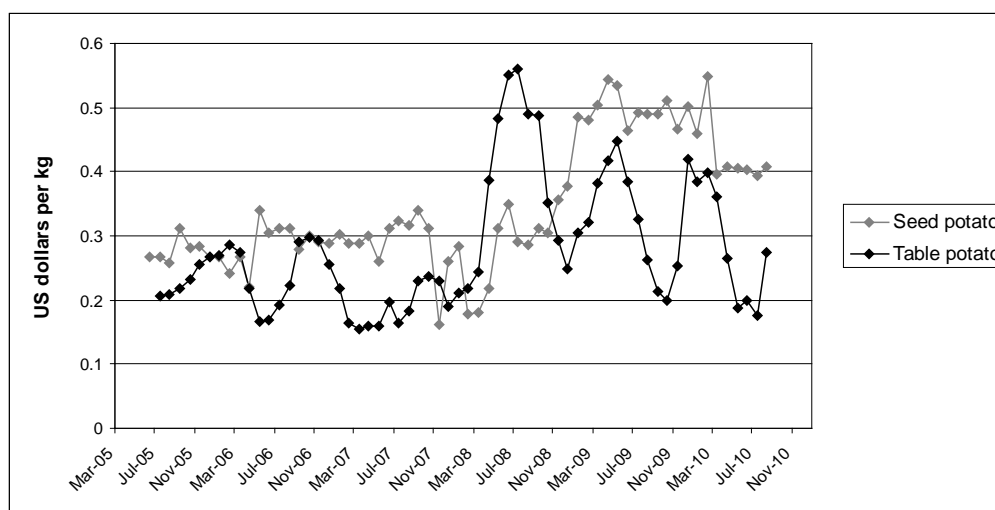


Figure 2.3. Price of seed potato (sold to farmers) and ware potato (bought from farmers) in CONPAPA/Tungurahua from 2005 to 2010.

3.3 SEED QUALITY

3.3.1 Before the intervention

Before the intervention the quality of potato seed in Ecuador was poor. The low national average yield (then at 7 t/ha) was attributed largely to the low quality of farmers' seed (Andrade et al. 2002) and has been described to be mainly due to high incidence of black scurf (*Rhizoctonia solani*) and Andean potato weevil (*Premnotrypes vorax*) (Fankhauser 2000).



Black scurf caused by *Rhizoctonia solani*.
Photo by Fabián Montesdeoca



Andean potato weevil (*Premnotrypes vorax*) larvae.

3.3.2. What changed as a result of the intervention

Physiological quality and healthiness. Data from CONPAPA/Tungurahua show that an acceptable quality of seed was produced, and the quality differences between seed lots stabilized from 2005 to 2010 (Figure 2.4).

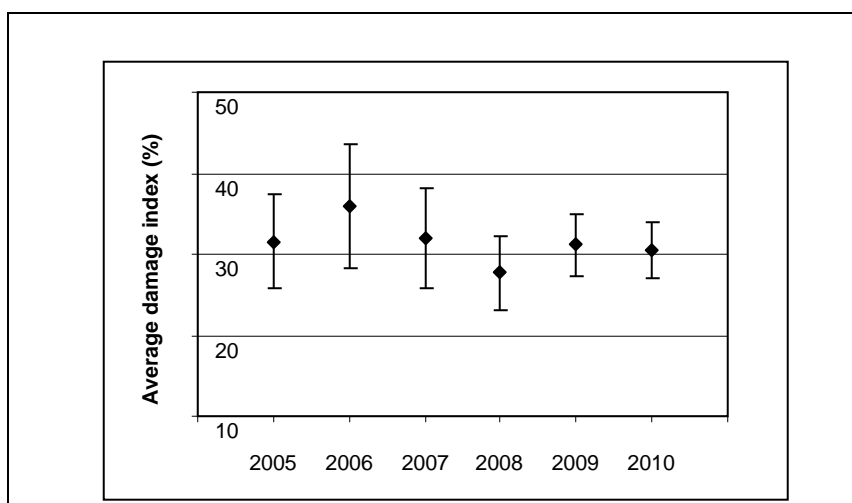


Figure 2.4. CONPAPA seed quality by average damage indexes. Low damage index = high seed quality. The seed-lots are graded as one of the following three categories: Quality 1 = damage index less than 32%, Quality 2 = damage index greater than 32 and less than 35%, or

4. Seed producers and seed availability

4.1 THE MODEL

How the CONPAPA seed system works. CONPAPA has created a semi-formal seed system based on a farmers' organization, a clear market-orientation, support from local partners, and the delivery of high-quality source seed from the formal seed system. The source seed is of varieties with market demand and that trained farmers multiply, following CONPAPA's internal quality control procedure. Seed is sold through CONPAPA to farmers who use this seed to produce ware potato for market niches (Figure 2.1).

First, a seed production plan is carefully adjusted to the expected monthly demand from CONPAPA's ware potato clients. CONPAPA buys source seed from INIAP of highly commercial varieties, then sells this seed to farmers who belong to the consortium and who received training in seed production.

CONPAPA invites selected farmers to become seed producers according to a set of requirements, including a history of complying with previous agreements and repaying loans, graduation from a farmer field school (FFS) on seed production, and willingness to take on the risks of investing in seed multiplication. Any farmer who expresses interest in becoming a seed producer and has been trained is accepted. Over the years, 35 seed producers have been trained in CONPAPA; as of 2014, 31 remain active (28 men, 3 women). The FFS taught by local extension partners and INIAP consists of at least six sessions on production costs; soil sampling; seed treatment and degeneration; cultivation techniques, including roguing; postharvest treatment; internal quality control; classification; marketing; and ethics.

After a farmer becomes a seed producer, the CONPAPA management office conducts quality control in three steps: (1) selecting the field before planting, (2) inspecting the field at flowering, and (3) inspecting harvested tubers (Montesdeoca et al. 2006; Narvaez 2005).

A seed field has to meet the following standards: minimum area of 0.25 ha, at least four years since the last potato crop, 50 m from the nearest potato field, located above 3,000 masl, and must have irrigation if planted in the dry season. The maximum incidence for nematodes (*Globodera pallida*) is 5 cysts/100 g of soil; for the Andean potato weevil, it is 10 adults/trap in 20 traps/ha.

At harvest, seed producers select healthy tubers of 30–120 g, removing any off varieties. Two hundred of the harvested tubers are randomly selected and inspected for disease, pest, and physical damage. Highly damaged seed lots are rejected, but the farmer can reselect and submit to a second grading procedure.

Seed producers are paid according to the grading. If the seed lot is not accepted, the tubers can be sold as ware potatoes and the farmer may lose his/her status as a seed producer. At one of CONPAPA's storage facilities, the seed is reselected, treated with insecticide (aluminum phosphide) or a Baculovirus treatment (to prevent tuber moth infestation), and re-sacked. The seed is stored and sprouted in new mesh sacks in warehouses located at 2,580–3,670 masl. Before sale, distinctive green CONPAPA labels

are attached to the sacks with the identification of the seed category—that is, QS1 (quality seed 1), QS2, or Selected—date of harvest, and name of the grower.

The seed is sold and delivered to the potato farmers at least 1 month before they need it. The better seed (QS1 and QS2) can be redistributed to seed producers. Source seed from INIAP can only be multiplied twice. Selected seed (the lowest quality) is normally sold to buyers outside of CONPAPA.

Ware potato producers in CONPAPA are advised to reuse the seed no more than four times, but no regulation is enforced. Farmers generally follow this recommendation for the ‘INIAP-Fripapa’ variety. The ‘Superchola’ variety, which is descended from the native Andean andigenum group, degenerates slower and farmers replant it six or seven times. Cultivation techniques such as positive selection (PS) and negative selection (NS) and good storage techniques (Cadena 2010) are being taught to ware potato producers through FFS, using training materials previously developed in Africa (Gildemacher et al. 2007a, 2007b) and adapted for Ecuador (Montesdeoca et al. 2012).

Although farmers reuse their own seed over several seasons, eventually the quality of the seed degenerates due to pathogen build-up. The MoA and the private sector are currently investing in RMTs in a large greenhouse to multiply elite planting material. Government programs to broadcast prices over the radio, insurance programs, and increased urban markets are encouraging farmers to produce more potato for sale, which increases the demand for formal seed potato.

Besides meeting the demand for well-known varieties, CONPAPA has also identified local demands for varieties. CONPAPA/Tungurahua has, for example, requested source seed of a new variety (‘INIAP-Libertad’), which responds to local white/yellow skin preferences and demands for earliness and disease resistance. CONPAPA/Bolívar requested source seed of improved native varieties, which are popular in that province but are not produced by the formal potato seed system.

4.2 BENEFITS FOR THE FARMERS

The CONPAPA experience has empowered smallholders and improved their income. CONPAPA seed allows farmers to enter higher paying markets by producing better ware potatoes. In CONPAPA/Tungurahua the seed system helped farmers sell more than 4,000 t of high-value ware potato from 2005 to 2010 (Table 2.1) and generated a \$1,340,408 turnover and \$150,545 revenue for CONPAPA.

Small-scale farmer income. The platform (marketing) activities and the formation of CONPAPA have resulted in significant impact by linking small-scale farmers to the new agricultural economy and increasing their income (Cavatassi et al. 2011; Hibon 2008; Thiele et al. 2011).

Small-scale farmer empowerment. CONPAPA has increased the smallholders’ self-esteem, influenced local policy-making and diminished the potential for social marginalization (Hibon 2008).

4.3 QUALITY ASSURANCE AND REGULATION

Internal seed quality control. Creating an internal seed quality control procedure was an important step in building the CONPAPA seed system, based on farmer training and on a new production protocol. It was crucial to have regulations that were external to each farmer but internal within the consortium.

The internal control contributes to a sense of willingness to comply, which earlier experiences with seed multiplication in Ecuador lacked.

Integration of components from informal and formal seed systems. CONPAPA blends the informal and formal seed systems. Producing widely adapted improved varieties, starting with high-quality source seed, and using quality control procedures are typical of formal potato seed systems. On the other hand, the absence of state regulations and allowing seed producers to save and replant their own seed are components of informal seed systems. The experience with CONPAPA suggests that the semi-formal seed system outperforms its predecessors (formal and informal seed systems) under Ecuadorian conditions in terms of improving small-scale farmers' seed quality and benefits.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

CONPAPA started when the demand for certified potato seed was very low: Less than 0.5% of the potato farmers in Ecuador received seed from the formal seed system (CNA 2002). The production of source seed was relatively low (46–150 t/year between 2005 and 2010; J. Velázquez, INIAP, pers. comm.), and most of it went to large-scale farmers, who produced certified seed for their own ware potato production.

- As Thiele (1999) suggests, demand for certified potato seed may be low because of:
- Market risk and the chance of frosts, hail, droughts, and pests
- Seed degeneration caused by viruses is slow in the Andes above 2,800 masl
- Bacterial wilt is absent in Ecuador
- Farmers do not recognize the benefits of formal seed
- Lack of good storage facilities
- High cost, as certified seed may represent more than 50% of production costs
- Farmers' limited access to credit.

Until recently, certified seed in Ecuador was of uneven quality and short in supply because the MoA lacked funds for transportation and salaries for the seed inspectors. Many of the disease tolerances in the regulations were impractical and almost impossible to comply with, so they were ignored. As a result, 99% of potato farmers in Ecuador used their own or other informal seed.

5.2 SEED HEALTH AND QUALITY

As mentioned earlier, a 2012 ministerial agreement established new protocols for producing certified seed, founded on the protocols used by CONPAPA. The new protocols are better aligned with the reality of Ecuadorian potato production. Some disease tolerances have been made more flexible, but the main change to the protocols is the procedure for visually inspecting seed lots using a composite damage index, the reduced use of serological diagnostics, and the procedure for producing certified seed (i.e., of category semilla común equivalent to QDS) of native varieties that are not multiplied from TC.

Impact studies on the effect of the new protocols have not been conducted, but the quality of certified potato seed seems to be improving and the volume of certified potato seed has increased in recent years. The registered seed fields in the formal system currently seem to receive increased support for field monitoring and postharvest inspection, improving the quality of certified seed, which previously was missing.

6. Seed multiplication tools and techniques

CONPAPA helps its smallholder members buy quality source seed, which the members multiply in their own fields, to sell as QDS to other members of CONPAPA and to other farmers, who produce quality ware potatoes for the fresh potato market. This is a practical method for smallholders. The seed producers did need training (e.g., FFS training to learn the techniques, especially the added quality control, which is supervised by CONPAPA). The success of this experience depends in part on increased demand for better potatoes from restaurants and supermarkets. This allows higher prices, which justify paying more for seed.

7. Lessons

The success and sustainability of the system depends on (1) collective action, (2) integrating the informal and formal seed systems, (3) demand-driven production, (4) internal seed quality control, and (5) initial funds and access to capital.

Collective action. Devaux et al. (2009) define collective action as “voluntary action taken by a group to pursue common interests or achieve common objectives.” From the start of the FFS to the creation of CONPAPA, collective action has been crucial for achieving most of the objectives that evolved with the CONPAPA experience. With improved farming capacity and the joint action of several actors (farmers, INIAP, NGOs, local governments, etc.; see Thiele et al. 2011), smallholders gained access to a profitable ware potato market that had been inaccessible (Cavatassi et al. 2011). For the first time, these farmers acquired a real demand for quality seed. CONPAPA’s egalitarian nature, and the social pressure it could bring to bear on farmers, strengthened their ability to produce seed.

Integration of components from informal and formal seed systems. CONPAPA’s semi-formal seed system blends components from informal and formal systems. This experience suggests that a semi-formal seed system can outperform formal and informal ones, at least under Ecuadorian conditions.

A semi-formal seed system must be implemented with careful consideration of local conditions; otherwise the system can easily become irrational and non-functional. The control system should include specific diagnosis of pest and diseases that are locally important only, and use generic diagnosis for phytosanitary problems that are not common locally, or for which the diagnosis equipment is not available (i.e., elimination of diseased plant material without specific diagnosis of the problem). If not, the control may easily become unnecessarily rigorous and costly. Flexible regulation is important, because a system loses authority if its standards are so rigorous that they cannot be fulfilled. For example, soil-borne diseases and pests are the main causes of potato seed degeneration in the Ecuadorian highlands, yet viruses are not a major limiting factor for seed production in Ecuador (Fankhauser 2000). CONPAPA has used costly enzyme-linked immunosorbent assay virus detection kits

and pheromone moth traps (when INIAP provides them), but these may be unpractical and not necessary in some areas above 3,000 masl.

Demand-driven production. In CONPAPA the demand for high-quality seed was driven by the demand for high-quality ware potato (from supermarkets and restaurants). CONPAPA identified a demand for ‘INIAP-Fripapa’ and other varieties by participating in activities with multi-stakeholder platforms (e.g., forums and exchange visits where farmers met buyers, consumers, and other actors in the potato chain; Cavatassi et al. 2011). The standards and volumes required by restaurants and supermarkets created the demand for quality seed.

Internal seed quality control. CONPAPA established an internal seed quality control procedure that ensured high-quality production of ware potatoes. The initial farmer training and development of a production protocol were indispensable. The internal regulations keep the system from collapsing and contribute to farmers’ willingness to comply, which was lacking in earlier experiences with potato seed multiplication in Ecuador.

Initial funds and access to capital. The CONPAPA seed system also received crucial support in the form of credit to small-scale farmers from local governments. Previously, more than 90% of Ecuadorian farmers had no access to credit and only 6% of all agricultural credit in the country was provided for potato growing, probably because it was considered high risk agriculture (Devaux et al. 2010). This credit allowed CONPAPA’s farmers to access high-quality seed and related technology, which had been inaccessible. However, the leaders of CONPAPA appear to have become comfortable in their roles as receivers of intervention aid. The farmers seem to have little desire to see their consortium become a self-sufficient seed system, operating free of donors. The farmers still see themselves as the weak link in the value chain. The farmer consortium leaders cultivate this image to continue tapping into development money from different sources, with the conviction that if they appear too successful they will lose opportunities for continued aid.

The seed system would be strengthened by improving the transparency of the potato value chain. The organizational structure of CONPAPA is still weak and shows little understanding of the rules and the procedures that it adopted to meet the requirements of the high-value markets. CONPAPA needs a manual of procedures and best practices for field crop management, postharvest and selection of potatoes, as well as clear rules that convey the price paid to the farmers for their products.

Acknowledgments

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References cited

- Andrade H, Bastidas O, Sherwood S. 2002. La papa en Ecuador. In: Pumisacho M, Sherwood S, eds. El cultivo de la papa en Ecuador. Quito: INIAP and CIP. p. 21–28.
- Bertschinger L, Keller ER, Gessler C. 1995a. Development of EPIVIT, a simulation model for contact- and aphid-transmitted potato viruses. *Phytopathology* 85(7):801–814.
- Bertschinger L, Keller ER, Gessler C. 1995b. Characterization of the virus × temperature interaction in secondarily infected potato plants using EPIVIT. *Phytopathology* 85(7):815–819.
- Cadena B. 2010. Validación de Cinco Sistemas de Almacenamiento con Cuatro Variedades de Papa (*Solanum* spp.) en Dos Localidades de la Provincia de Tungurahua. PhD dissertation, Universidad Central del Ecuador.
- Cavatassi R, Gonzalez M, Winters P, Andrade-Piedra JL, Espinosa P, Thiele G. 2011. Linking smallholders to the new agricultural economy: The case of the plataformas de concertación in Ecuador. *Journal of Development Studies* 47(10):1545–1573.
- [CAN] Censo Nacional Agropecuario. 2002. III Censo Nacional Agropecuario. Quito: Instituto Nacional de Estadísticas y Censos, Ministerio de Agricultura y Ganadería.
- Devaux A, Ordinola M, Hibon A, Flores R. 2010. El sector papa en la región andina: Diagnóstico y elementos para una visión estratégica (Bolivia, Ecuador, y Perú). Lima: CIP
- Devaux A, Horton D, Velasco C, Thiele G, López G, Bernet T, Reinoso I, Ordinola M. 2009. Collective action for market chain innovation in the Andes. *Food Policy* 34(1):34–38.
- Fajardo J, Lutaladio N, Larinde M, Rosell C, Barker I, Roca W, Chujoy E. 2010. Quality declared planting material: Protocols and standards for vegetatively propagated crops. FAO Plant Production and Protection Paper 195. 126 p. (Available from <http://www.fao.org/docrep/013/i1195e/i1195e00.pdf>) (Accessed on 12 August 2014)
- Fankhauser C. 2000. Seed-Transmitted Diseases as Constraints for Potato Production in the Tropical Highlands of Ecuador. PhD thesis, Swiss Federal Institute of Technology, Zurich, Switzerland.
- FAO. 2006. Quality declared seed system. Rome: FAO plant production and protection paper 185. (Available from <http://www.fao.org/docrep/009/a0503e/a0503e00.htm>) (Accessed on 25 July 2011)
- FAO. 2010. The second report on the state of the world's plant genetic resources for food and agriculture. (Available from <http://www.fao.org/docrep/013/i1500e/i1500e00.htm>) (Accessed on 25 July 2011)
- Gildemacher P, Demo P, Kinyae P, Nyongesa M, Mundia P. 2007a. Selecting the best plants to improve seed potato. *LEISA Magazine* 23(2):10–11.
- Gildemacher P, Demo P, Kinyae P, Wakahiu M, Nyongesa M, Zschocke T. 2007b Select the Best: Positive Selection to Improve Farm Saved Seed Potatoes. Trainers manual. Lima: CIP.

- Gildemacher P, Demo P, Barker I, Kaguongo W, Woldegiorgis G, Wagoire WW, Wakahiu M, Leeuwis C, Struik PC. 2009. A description of seed potato systems in Kenya, Uganda and Ethiopia. *American Journal of Potato Research* 86:373–382.
- Hibon A. 2008. Apoyo a la implementación de procesos de generación de valor agregado en el CONPAPA. Report. Quito: FORTIPAPA, INIAP, and CIP.
- Montesdeoca F, Narváez G, Mora E, Benítez J. 2006. Manual de Control Interno de Calidad (CIC) en Tubérculo - Semilla de Papa. Quito: INIAP, COSUDE, Papa Andina.
- Montesdeoca F, Panchi N, Pallo E, Yumisaca F, Taípe A, Mera X, Espinoza S, Andrade-Piedra J. 2012. *Produzcamos Nuestra Semilla de Papa de Buena Calidad - Guía para Agricultoras y Agricultores*. Quito: CIP, INIAP, CONPAPA, and Fundación McKnight.
- Narvaez GA. 2005. Ajuste de los Parámetros del Protocolo de Control Interno de Calidad (CIC) Propuesto por FORTIPAPA para la Producción de Semilla de Papa Registrada y Certificada en Base a Situaciones Reales de Campo en Cuatro Localidades. PhD Dissertation, Universidad Central del Ecuador.
- Thiele G. 1999. Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27(1):83–99.
- Thiele G, Devaux A, Reinoso R, Pico H, Montesdeoca F, Pumisacho M, Andrade-Piedra J, Velasco C, Flores P, Esprella R, Thomann A, Manrique K, Horton D. 2011. Multi-stakeholder platforms for linking small farmers to value chains: Evidence from the Andes. *International Journal of Agricultural Sustainability* 9:423–433.

CHAPTER 3

Aeroponic seed and native potatoes in Peru

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Abstract

Farmers in Cajamarca, in the remote northern highlands of Peru, grow native potatoes with low yields, about 5 t/ha. A local NGO, the Association for the Sustainable Development of Peru, secured funding from a gold mining company to fund community projects. The NGO organized farmers to produce potatoes for market, was able to link the communities to supermarkets, and helped them earn better prices for their potatoes. This motivated the farmers to produce more. The farmers produced seed of three modern varieties and three native ones, which were reintroduced into the area. The project built a greenhouse to produce high-quality minitubers using aeroponics, which the farmers could plant in their open fields. In combination with chemical fertilizer, the new seed helped to increase yields to about 15 t—three times higher than before the project started. It is unclear whether the achievements of the project are sustainable or whether they will help to conserve native potato varieties.

Rationale

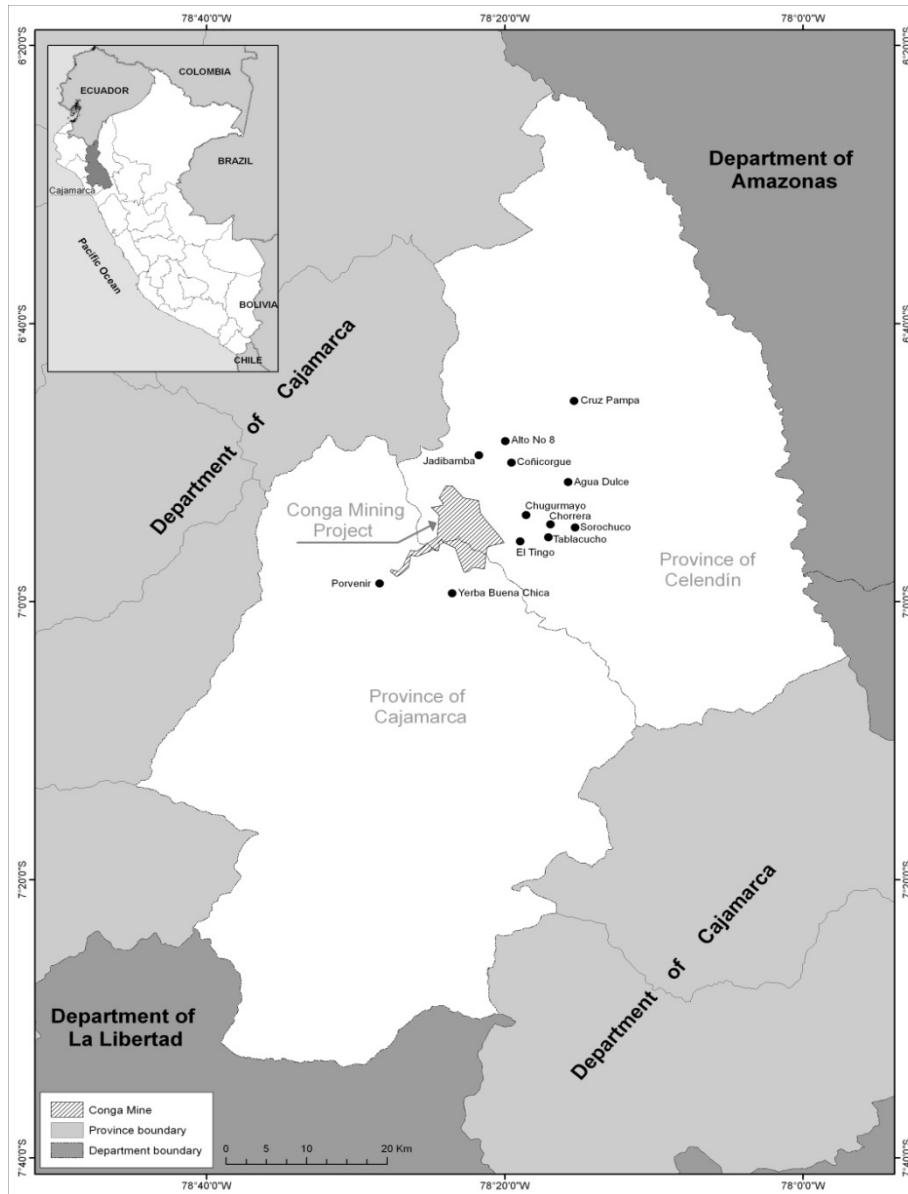
This is one of two case studies in this volume whereby the farmers are working with a native crop in its area of origin (the other one is yam, in Nigeria, although Ecuador is very near the center of origin of the potato). The farmers in this study are still growing native potatoes, and it is important to encourage farmers to conserve this biodiversity. Selling native potatoes is one way to encourage their survival in the field.

The project tried to contribute to a better quality of life for potato farmers by generating income and employment by producing quality seed potato, to develop farming techniques with a market approach, to preserving biodiversity, and to transmitting new technical knowledge that was to be validated under farmers' conditions.

1. The intervention

The project took place in the Conga region of northeast Peru, an area at an altitude of more than 4,000 masl and a unique wetland. Here, the proposed Conga Mine (of the Yanacocha Mining Corporation) has come into conflict with 32 communities, as the Conga Mine would drain four lakes to

make two open-pit gold mines, at a cost of \$4.2 billion. The communities and local government have opposed the project.

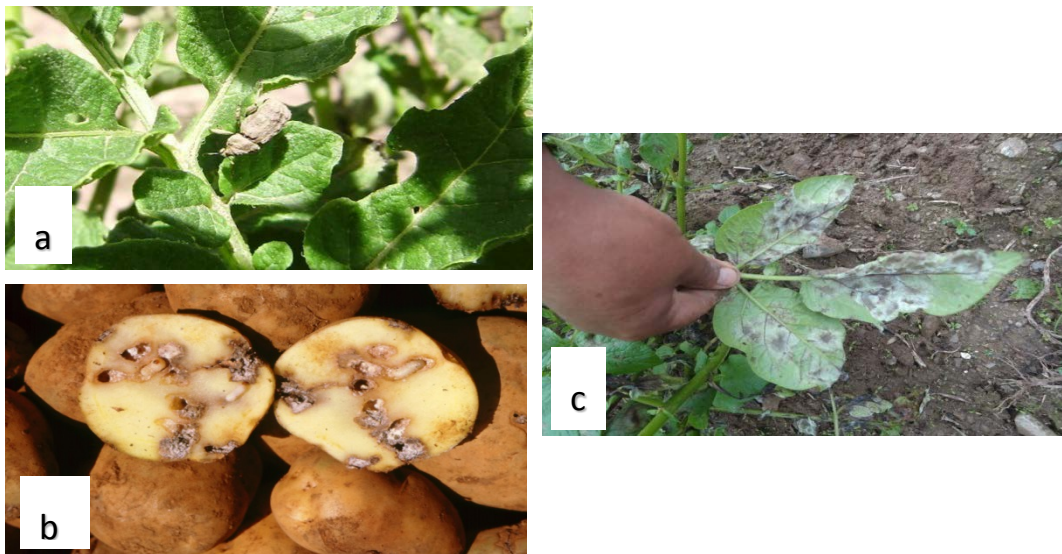


Potato is the most important crop grown and eaten in this area. Yields of native potato varieties are 5 t/ha, but improved varieties can yield twice as much. Only 20% of the potato harvest is sold in local markets, while the rest is saved for the cooking pot and for seed.

The villages in the Conga region are located between 2,600 and 4,200 masl. Heavy metal ores in the Andes tend to be found in high areas, where ecosystems are fragile. The gold and silver deposits of Cajamarca have attracted large-scale mining, environmental damage, and grassroots protests for years. Farmer organizations are limited in this area, but there are functioning irrigation boards with farmer representation and an association of farmers in the watershed of Jadibamba.

Agricultural land is privately owned, with an average family having 3 ha of fields to grow crops such as potatoes, oca (a native tuber—*Oxalis tuberosa*), other tubers, roots, and grains. The main potato varieties are three white, improved varieties ('Perricholi', 'Liberteña', and 'Amarilis'); 'Huayro' (a brown and purple native potato); and 'Peruanita' (a bright yellow native variety). Potatoes are planted in the lower country in June–July and harvested in January–February. In the highlands, planting is from October to November and the harvest is from May to June. The higher areas are covered in vast areas of rough pasture of native needle grass (*Ichu* spp.).

In all the villages in the Conga area, the seed potato comes from the previous harvest. The main potato health problems are late blight (LB) (*Phytophthora infestans*), Andean potato weevil (*Premnotrypes vorax*), and flea beetle (*Epitrix* sp.).



Adult (a) and larvae (b) of potato weevil, and late blight on potato leaves (c).
Photos by Ricardo Orrego

To implement this project, the NGO ADERS Peru (Association for the Sustainable Development of Peru) established a strategic alliance with CIP; the General Direction of Agricultural Competitiveness; National Agricultural Research System (INIA, including the INIA experimental station in Baños del Inca, near Cajamarca); the National Agricultural Health Service; and the Andean Potato Initiative, a project of FAO.

seed of native potatoes and improved varieties, which will generate an average monthly income of \$667.

Theory of Change

The project was built on the idea that by training farmers and organizing them to grow certified seed and table potatoes of native and improved varieties, farmers would be able to sell quality potatoes year-round to supermarkets and improve their incomes. This was rather a large leap to make for farmers who had been growing potatoes mostly to eat at home, with a small surplus sold in the local market.

The farmers had also been growing and using their own seed. They would now become specialists in growing not only certified seed, but the even more demanding pre-basic seed. The smallholders would provide specified amounts of fine tubers to the supermarket, and buy potatoes from others to make up for seasonal shortfalls. In one step, the farmers were to go from subsistence farming to producing formal-sector seed, fancy produce for supermarkets, and to become commodity buyers. The assumption behind this shift was that training and organization were enough to make these ambitious changes. The theory of change was overly ambitious.

Framework: Potatoes in Peru

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Policymakers						Set standards for certified seed
National research		INIA registered farmers as seed producers				
International research	CIP-provided source seed					
Traders (local markets)						Some seed quality problems ascribed to traders
Private seed sector						
Farmer organizations	Had access to seed from aeroponics greenhouses	FGs created by ADERS			Demanded native varieties	
NGOs	ADERS provided greenhouse	ADERS facilitates	ADERS subsidizes	ADERS trains farmers	Provided seed of 3 native varieties	ADERS provides quality control
Private sector processors				Supermarkets bought ware potatoes, stimulating demand		
Seed users	Mostly the organized farmers themselves					

2. General context

2.1 TYPE OF FARMING SYSTEMS

Potato viruses tend to reproduce faster in warmer weather (e.g., at lower elevations) (Bertschinger et al. 1995). In the Andes, potatoes can be grown from local seed at high elevations. Here the cool weather is favorable for the crop and reduces degeneration caused by viruses, which often makes it impossible to reproduce seed potatoes in lower areas. Potatoes have been grown in the area for thousands of years, and local people know how to save the seed from one year to the next.

Potatoes are planted once a year, in the rainy season, from October to March. To fit into the rugged, mountain landscape, fields are relatively small and are plowed by oxen; weeding and other tasks are done by hand. In some years, diseases may be a problem, especially LB.

There has been technical change in the farming system, mostly due to the active role of agro-dealers. Most farmers are using improved varieties, chemical fertilizers, and pesticides routinely, especially for commercial varieties (much less frequently on varieties to eat at home). The highland communities have few chances to sell their products in the big cities, but there are small, local fairs where farmers can sell small amounts or barter their products for other foods. Some farmers obtain seed at these fairs, especially to get new varieties, including native ones, from other areas.

2.2 MARKET IMPORTANCE OF THE CASE-CROP FOR FARMERS

In the northern highlands of Peru, Cajamarca is one of two important production zones that supply commercial potatoes to local markets. Villages near highland cities sell native varieties in these markets, where local consumers know and demand these varieties. But lowland cities also demand improved, commercial varieties.

The prices of all varieties rise and fall with supply and demand. Prices fall with the harvest in January and February and begin to rise again after April or May. There is a naïve, but widespread, opinion held by farmers and NGOs alike, that potato traders fix the final price paid to the farmer. In truth, potato dealers compete in a volatile market with many producers and many consumers, and traders have little or no control over prices.

However, to sell in the large, wholesale markets of big coastal cities, it does help to have contacts, a truck, and money to buy a load of potatoes. This prohibits most smallholders from selling directly to cities. However, ADERS was able to link farmers to new alternative markets by reaching an agreement with a local supermarket to bring in a steady supply of commercial and native potatoes. Like CONPAPA in Ecuador (see Chapter 2 in this volume), the ADERS case was heavily influenced by Papa Andina's Participatory Market Chain Approach, which was applied in both countries (see Chapter 2 in Thiele et al. 2011). CONPAPA is a farmers' association, whereas ADERS is an NGO, but the two organizations played similar roles as brokers between farmers and potential buyers.

2.3 GENERAL SEED SECTOR CHARACTERISTICS

There are two seed production systems: formal and informal. The formal one is regulated by legal regulations and is covered by a certification process aimed at ensuring the health and quality of the seed. The informal system is managed by farmers without state intervention, while maintaining a certain quality of the seed.

The informal system satisfies 99% of potato growers with seed. This system has the advantage of being affordable, much cheaper than certified seed, while also being available right in the villages where potato farmers live. There are some quality problems, especially when the seed is bought from outside traders rather than trusted neighbors.

2.4 TRENDS, DEVELOPMENTS, ONGOING CHANGE OF CONTEXT

Peruvian consumers were switching from potatoes to meals based on rice, especially on the coast and among the middle class. For the past several years, several initiatives have increased consumer interest in the potato. One was the expansion of new markets in Peru (especially large supermarkets, where potatoes are sold in attractive packaging). There have also been government efforts to encourage people to eat potatoes, including Peru's national potato day (every 30 May, established in 2005). 2008 was the international year of the potato. That same year, there was the international gastronomic fair, *Mistura*, started by beloved Peruvian chef Gastón Acurio, who is leading the movement in Peru to put the potato back on the menu, especially by inventing and serving new dishes based on native potato. The food-manufacturing industry is also using native potatoes to make attractive products like purple potato chips. All of this is creating excitement about native varieties and opportunities for smallholders in the highlands.

An important policy change is the new seed potato regulations that formalize the informal seed system, particularly to help conserve the biodiversity of farmers' native varieties, as well as the varieties of small and medium commercial seed producers.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

Farmers point out that they have grown seed for years as their ancestors did. Potatoes were planted by HH, with or without labor exchange from others, according to farmer's own experience, and without training from outsiders. They were fertilized mainly with composted barnyard manure (a complete, slow-releasing fertilizer excellent for potatoes, provided one applies enough of it).

During harvest, farmers heaped the potatoes into mounds in the field, and HH members went through the tubers one by one, classifying them by size, shape, and number of eyes, and discarding the damaged ones. The smaller tubers (which are easiest to plant) were chosen as the next year's seed, and the rest were eaten.

The harvest was stored in thatched huts or in dark, dry places. Projects often assumed that the seed was of poor quality; this was not always true. Seed was rarely obtained from distant areas.

Farmers used several mechanisms to remain self-sufficient in seed. One was *minka*, or labor exchange, where people who help a farmer to harvest potatoes may be paid partly in kind. Farmers also bartered other farm products for potatoes. In some places, farmers bought seed from neighboring farmers, or gleaned potatoes from harvested plots (*pallaqueo*), and finally bought seed in the local market.



Local seed is not necessarily always poor
Photo by Ricardo Orrego

Andean potatoes have suffered from pests and diseases since ancient times, but losses became greater during the twentieth century (Ortiz 2006). Before then, pest populations were probably kept low by the small size of fields, long fallows, and great distances between fields (Parsa 2010).

Farmers in the study area may have felt that the seed could be maintained over time without degenerating because the high altitudes did not favor the build-up of diseases, especially viral ones. Yet farmers did observe that over time, the seed no longer produced as before. The farmers suggested that the seed was “tired” of the soil where it was being grown.

Farmers had no way of knowing that seed degeneration was the effect of viruses. Farmers could not directly observe viruses, only their symptoms (e.g., yellowing and green-yellow mosaic patterns on the leaves).

3.1.2 What changed as a result of the intervention

It was difficult for farmers to work in commercial partnerships; there was always distrust even though the project ensured that each person worked the same amount. However, with support from ADERS, the farmers did manage to form five producer associations. Farmers assumed that this was a new opportunity to work with the development community, and that they would benefit by guaranteed sales to new markets.

The FFS training, the use of quality seed, and high yields motivated farmers to improve their work in the field. As farmers began selling to supermarkets, they received higher and more stable prices for their potatoes, which improved farmers’ income and HH satisfaction.

3.2 AFFORDABILITY OF THE NEW SEED POTATO

Three commercial varieties and three native ones were predominant in the area. Owing to weather, pests, low yields, food shortages (when people are forced to eat seed), and the loss of potato-growing to forage and other crops, some potato varieties had been lost. The project reintroduced landraces, especially purple and red ones ('Cceccorani', 'Ambar', 'Leona', 'Putis', 'Moray', and 'Yana Shucre'), which are used to make chips. Improving the farmers' seed business helped to boost the commercial development component.

ADERS reports indicate that the area is ideal for producing two seasons per year. In 2012, 217 ha of potato were planted: 84 ha in the small season (June–January), with irrigation, and 133 ha in the main season (in the rainy season, October–May).

3.3 SEED QUALITY

The project is funded by Los Andes Association of Cajamarca (ALAC), which is also responsible for monitoring and supervising field activities. ALAC is part of the CRS of the Cajamarca Mining Corporation.

ADERS decided to deliver certified seed from the formal system to farmers, in order to start with healthy seed and ensure a good harvest. ALAC launched a tender to seed growers in Cajamarca to provide quality seed. Unfortunately, local seed producers were not producing certified seed, so ALAC had to source the seed from producers in other areas of the country.

Farmers observed the behavior of this new seed and saw that yields increased by 25%. However, certified seed was provided for free by ADERS, and at present it is not clear whether farmers would buy certified seed on their own.

3.3.1 Before the intervention

Baseline studies showed that farmers' yields were low due to the constant replanting of their own seed, which increased tuber infection and led to degeneration of the seed. The reports indicate that crop was attacked by LB, Andean weevil, and flea beetle.

3.3.2 What changed as a result of the intervention

The use of fertilizer and certified seed did increase yields. A similar ADERS project in Cajamarca reported raising the yields of native potatoes from 4–5 t to 9, by using certified seed and fertilizer (Fuentes et al. 2009). From 2001 to 2011, potato yields in the project area tripled from about 5 t/ha to 15 or more. This result allowed farmers to observe the effect of seed quality combined with the use of chemical fertilizer. Depending on the costs of seed, fertilizer, and the price paid for potatoes, it may be a substantial increase in family income.

The project found a new market that ensures farmers a fixed and stable income from selling potatoes: paying US \$0.50/kg.

4. Seed producers and seed availability

4.1 THE MODEL

The model has two components: (1) strengthening the capacities of the farmers and (2) linking informal and formal seed systems.

Capacity building. Training farmers to manage the potato crop through the FFS was important because the field school organizes farmers into work groups which share a learning experience and an analysis of their agro-ecology and decision-making. FFS sessions were conducted on farm technology, organization, and marketing. The sessions covered issues of organizational development aimed at building and strengthening the farmers' association, and held decentralized workshops for training local facilitators and authorities.

To facilitate the FFS, 32 farmer facilitators (two per FFS) were selected. These men and women were democratically elected by their communities. The facilitators were trained in an intensive, systematic, and participatory way on the following topics: the project objectives and operational strategies, the FFS method, the supply chain, good agricultural practices, native potato production, postharvest, seed selection and classification, and native potato storage, as well as how to prepare the operating and quality standards of the marketing and sales plan required by the market.

Linking informal and formal seed systems. The project presents a combination of both production systems. The reuse of seed by Andean farmers and rearing of native varieties are framed within the informal system. Sixteen native potato plots (one per FFS) were established jointly by the project and beneficiaries. Each farmer also planted a 0.5-ha plot of native potato for the market. These plots were managed with the technical recommendations learned in the FFS, combined with ADERS's technical proposal containing instructions on seed selection, planting, crop management, harvesting, selection, classification, storage, and sales.

At the beginning of the project, ADERS bought certified seed of commercial varieties and delivered it to farmers, who were able to use it to grow their own certified seed for following years. During the first year, potatoes were grown from certified seed brought in from other areas.

During the first year, each of the 60 farmers planted 0.50 ha, which increased to 1 ha after the third year, until the fifth year. ADERS delivered the certified seed to farmers under a system of revolving funds (after harvest, farmers will return the amount of seed they received), supporting farmers with organic fertilizers and pesticides.

The "minitubers" are produced in a greenhouse by planting the seed potato in net pots, to allow the roots to grow down into a tube, without any soil. The roots grow in the air and are misted with water and nutrients. The roots produce small tubers, or minitubers.

4.2 BENEFITS FOR THE FARMERS

The minitubers are then planted in seed multiplication fields run by individual farmers. The farmers have been impressed by the vigorous plants emerging in uniform stands from the fields. The farmers' perceptions were confirmed at harvest.

Potato yields tripled from 5 t/ha in 2001 to 15–25 t/ha in 2012, thanks to chemical fertilizer, clean seed, and management recommendations learned in the FFS. Meanwhile, over the same period, the price of potato per arroba (25 lb. or 11.5 kg) went from \$1.67 to \$6.00. The greater yields and prices improved profitability by about 360%.

5. Regulation and policy affecting farmers' use of quality seed

Current regulations are overly demanding and impractical. About 99.5% of the seed potato in Peru is provided by the informal system. The remaining 0.5% may comply with health standards set by the regulations, but the informal seed is of uneven quality.

Experiences from elsewhere indicate that there are informal producers with good seed potato, which sells for 40% less than certified seed. These producers have permanent buyers who trust the quality of their seed and know that it will yield a good harvest. Informal seed can be good, as long as the producers are knowledgeable, honest, and responsible.

5.1 GENERAL POLICIES AND SEED REGULATION

The Peruvian general regulations specify seed quality based on four categories (genetic, basic, registered, and certified), each with different standards of quality based on field sanitation. As the seed is multiplied, it is reclassified into successively lower categories (Bentley et al. 2001).

The overly stringent regulations, weak structure of the certifying organization, poor transportation for staff, job insecurity, and low inspectors' salaries, combined with market demand for cheap seed, have influenced a change toward informality. Weaknesses in the formal system allowed some unscrupulous seed traders to buy ware potatoes and sell them as seed. However, some farmers who were once registered as seed growers have become "informal," producing good, healthy seed which is even better than the formal system.

5.2 SEED HEALTH AND QUALITY

Through a resolution of 2012, the General Regulations of seed have been modified. Specific new regulations for seed potatoes are currently being analyzed and discussed, to reconsider the feasibility of the previous certification protocol.

This new regulation proposes including uncertified seed in a new category ("declared"), which will require registered seed growers to "make a statement" about the production and apply an internal quality control protocol. Another new category will also be included, "traditional," which will benefit farmers who maintain native varieties. This proposal will aim to formalize the informal system producers.

6. Seed multiplication tools and techniques

The project proposed rearing seedlings provided by CIP in vitro to remove the viruses from the plants.

ADERS considered the market to be crucial for generating income, and saw that the best way to keep a market satisfied is by providing a steady supply and quality of potato. It therefore built a greenhouse to produce minitubers of commercial varieties and landraces using aeroponics. The greenhouse has an area of 105 m² and a production capacity of 24,000 minitubers every 6 or 7 months. Minituber production began in 2012, with seedlings of native potatoes 'Huagalina', 'Cceccorani', 'Ambar', 'Leona', 'Yellow Tumbay', and 'Peruanita' harvested between November and December.

The generation of quality pre-basic tubers will allow farmers to keep the seed healthy for two or three generations and obtain high yields. The production of commercial varieties will help meet the demands of agroindustry (for making purple potato chips) and of supermarkets.

7. Lessons

Organization. In the FFS, farmers learned to work as an organized group and to trust each other. Learning is efficient if the topics are based on the participants' experiences, and satisfy the farmers' expectations for crop management.

New markets. Supermarkets are a new and rapidly growing opportunity to distribute high-quality commercial and native potatoes to specialized consumers in Peru, while encouraging people to eat varieties which may be new to them. This helps to secure sales and stable prices throughout the year, generating an increase in income. It also promotes the use of high-quality seed. It remains to be seen what effect projects like this one will have on potato biodiversity.

New technology. Aeroponics is an efficient technology if it is handled by a company or an organization that has an adequate budget, stable and trained technical staff, and the logistical support needed. Under more realistic circumstances, aeroponics could collapse.

Minitubers are good seed, but they are expensive and farmers in this case probably cannot afford them without project support. ADERS will deliver that seed to farmers under some form of recovery (where farmers repay the seed in kind after harvest), but that will be sustainable only during the life of the project, after which the system will almost certainly stop working.

Funding sources. Nontraditional donors (such as gold mining industries) can be a source of funding for NGOs and rural communities to try new activities, such as innovations to produce seed of native potatoes. However, the sustainability of this approach remains to be seen.

References cited

- Bentley JW, Tripp R, Delgado de la Flor R. 2001. Liberalization of Peru's formal seed sector. *Agriculture and Human Values* 18(3):319–331.
- Bertschinger L, Keller ER, Gessler C. 1995. Characterization of the virus × temperature interaction in secondarily infected potato plants using EPIVIT. *Phytopathology* 85(7):815–819.
- Fuentes C, Adachi I, Meléndez R, Pajares D, Vera L, Vidal C. 2009. *Planta de Puré Instantáneo de Papas Nativas en Cajamarca*. Lima: Universidad ESAN. 184 p.
- Ortiz O. 2006. Evolution of agricultural extension and information dissemination in Peru: An historical perspective focusing on potato-related pest control. *Agriculture and Human Values* 23(4):477–489.
- Parsa S. 2010. Native herbivore becomes key pest after dismantlement of a traditional farming system. *American Entomologist* 56(4):242–251.
- Thiele G, Quirós CA, Ashby J, Hareau G, Rotondo E, López G, Paz Ybarnegaray R, Oros R, Arévalo D, Bentley J, eds. 2011. *Métodos Participativos para la Inclusión de los Pequeños Productores Rurales en la Innovación Agropecuaria: Experiencias y Alcances en la Región Andina 2007–2010*. Lima: Programa Alianza Cambio Andino. 197 pp.

CHAPTER 4

Adapting a yam seed technique to meet farmers' criteria

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Abstract

Seed yam is costly, and can carry pests and diseases. To reduce costs and to manage seed health, in the 1970s the yam minisett technique (YMT) was developed, which involved cutting yams into small pieces to be used as seed. Few farmers adopted the technique, in part because of the high labor requirements of making a nursery to sprout the pieces of tuber. In 1992, a project funded by the UK's Department for International Development introduced fungicide and insecticide treatment to improve the survival of the YMT. The adapted yam minisett technique (AYMT) was developed during 2003–2006 in response to the technical problems of the YMT. The AYMT involved larger pieces of yam, dipped in a solution of fungicide and insecticide, to help manage pests and to ensure that more of the pieces survived. This allowed farmers to skip making the tedious seedbed, and to plant directly in the field. The technique was adapted on four on-farm trials. About 400 farmers in Kogi State, Nigeria, have tried the technique. They had credit to buy the pesticides. Although various subsequent projects have promoted the AYMT, farmer response to the technique is yet to be quantified.

Rationale

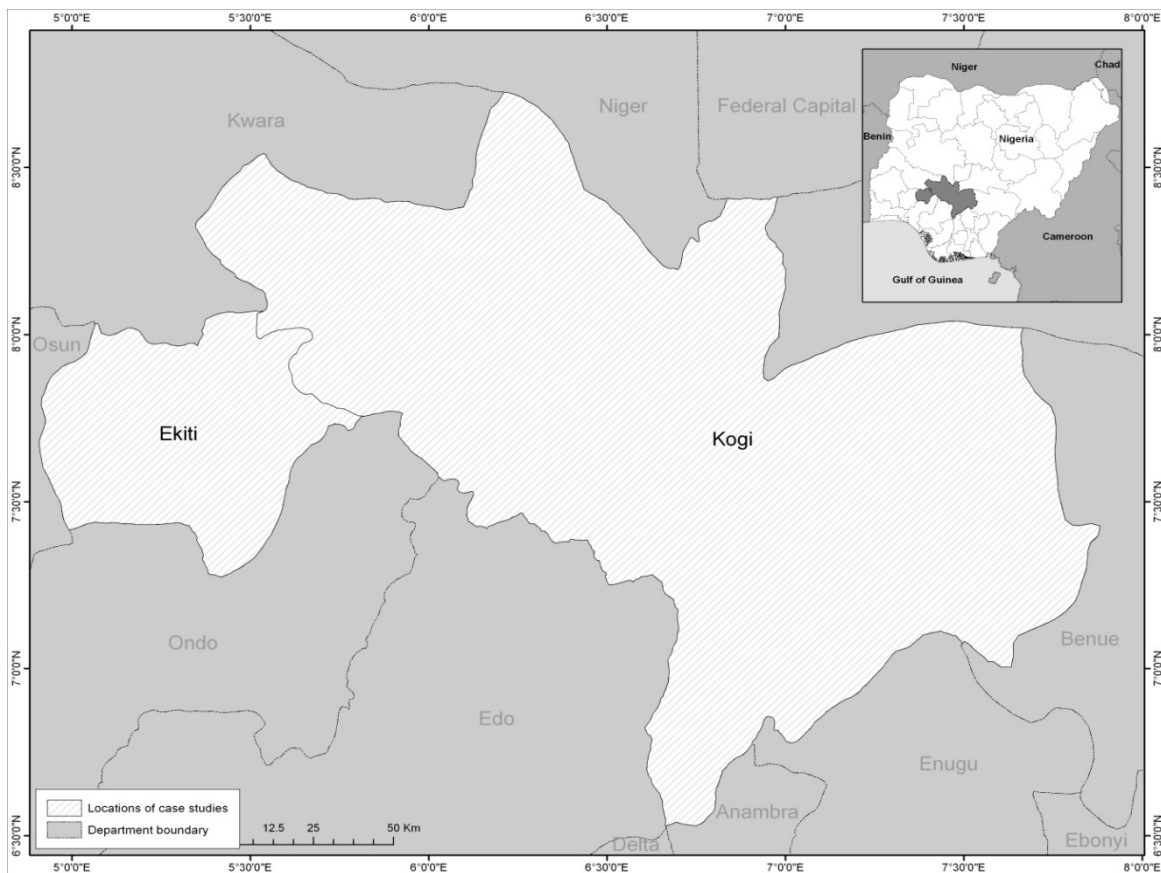
To increase awareness of yam pest and disease constraints, and to evaluate and promote environmentally sound and economically beneficial crop protection practices for clean seed yam production in Kogi and Ekiti states of Nigeria.

1. The intervention

Yam (*Dioscorea* spp.) production is constrained by many pests and diseases (Bridge 1982), and by the high cost of planting materials which constitutes between 33% and 50% of the production cost of yam in sub-Saharan Africa (SSA) (Asare-Bediako et al. 2007; Kambaska et al. 2009). Yams are usually propagated by planting small tubers or pieces of tuber, which carries over tuber-borne pests and diseases between seasons. Minisett technology promoted in this project came from the efforts of researchers to reduce the cost of producing ware yams (Otoo et al. 1987; Ibana et al. 2009). The quality

of seed yams determines the returns a farmer gets at the end of the season. Therefore, it is crucial to produce planting materials that are free from pests and diseases.

In 1992 the initial project funded by the UK's Department for International Development (DFID) aimed to develop a suite of plant health practices to resolve the emerging pests and diseases linked to seed yams. The project identified a range of readily available fungicides that effectively improves the survival of minisetts of white yams (*D. rotundata*) and (less so) of water yams (*D. alata*). The project case under review, "Evaluation and Promotion of Crop Protection Practices for Clean Seed Yam Production Systems in Central Nigeria," was also funded by DFID (R8278) from January 2003 to March 2005. Its objectives were to (1) increase the awareness of yam pest and diseases, and (2) evaluate and promote environmentally sound and profitable clean seed production in Kogi and Ekiti states of Nigeria. This case study examines both objectives and their results.



In 2003–2004 and 2004–2005, there were four formal (controlled) on-farm trials on which researchers also stimulated and supported simple direct comparison of treated versus farmer practice with dozens of farmers, across states, and varieties. These interactions increased farmers' awareness of pests and diseases, while evaluating sound practices for producing clean seed yam. The trials entailed planting tuber pieces of about 100–150 g pretreated with a cocktail of a fungicide and

insecticide/nematicide. A baseline study before starting the project gave information about farmers' perceptions about the sourcing of planting materials in the study areas. The on-farm trials gave the farmers an improved understanding of current practices and economics of the seed and ware yam production, and shed light on farmers' perceptions and knowledge of yam pests and diseases and their control.

Theory of change

The baseline study found that most yam growers buy their seed yams, in order to get good quality seed. Some farmers also hold back seed, or milk their yams to produce seed. Credit emerged as a key constraint for producing clean seed yams. This study also assessed the economic viability of yam miniset technology and found that producing seed yams in sufficient quantity is not enough and the seed must also be free from pests and diseases in order to:

- Maximize profits
- Manage pests and diseases
- Increase yam production
- Produce quality ware yams fit for export.



Traditional seed yam farmer in Nigeria
Photo by IITA

Framework: Yams in Nigeria

Stakeholder	Availability/ supply	Accessibility			Quality: variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Polymakers					There was no explicit national policy for yam QDS	
National research				Received information about AYMT		
International research	IITA fostered AYMT technique	Seed yam was expected to be produced on-farm	The technique lowers costs	Held field days, demos, & training for extension agents, farmers, & journalists	The yams are native to Nigeria. The technique works with any variety	Larger pieces of yam & pesticide dip help keep seed pest free
Traders (local markets)						
Private seed sector			Seed growers could adopt the technique			
Farmer organizations						
NGOs			The Diocesan Development Services helped develop AYMT			
Private sector processors			There are many active yam buyers			
Seed users		Farmers are expected to adopt the technique				

2. General context

2.1 TYPE OF FARMING SYSTEMS

Yams are grown mainly in West and Central Africa—Nigeria, Benin, Togo, Ghana, Côte d’Ivoire, and Cameroon. World production of yam in 2011 was 57.1 million t, with about 92% from West Africa; Nigeria contributes about 65% of the world total (FAOSTAT 2014). Of about 600 *Dioscorea* species (including wild ones), *D. rotundata* (white yam) is the most important food yam species in West Africa. Yam production is dominated by resource-poor farmers with holdings of 1–2 ha or less (Migap and Audu 2012). Smallholders produce about 95% of the yams in Nigeria (see Figure 4.1 below).

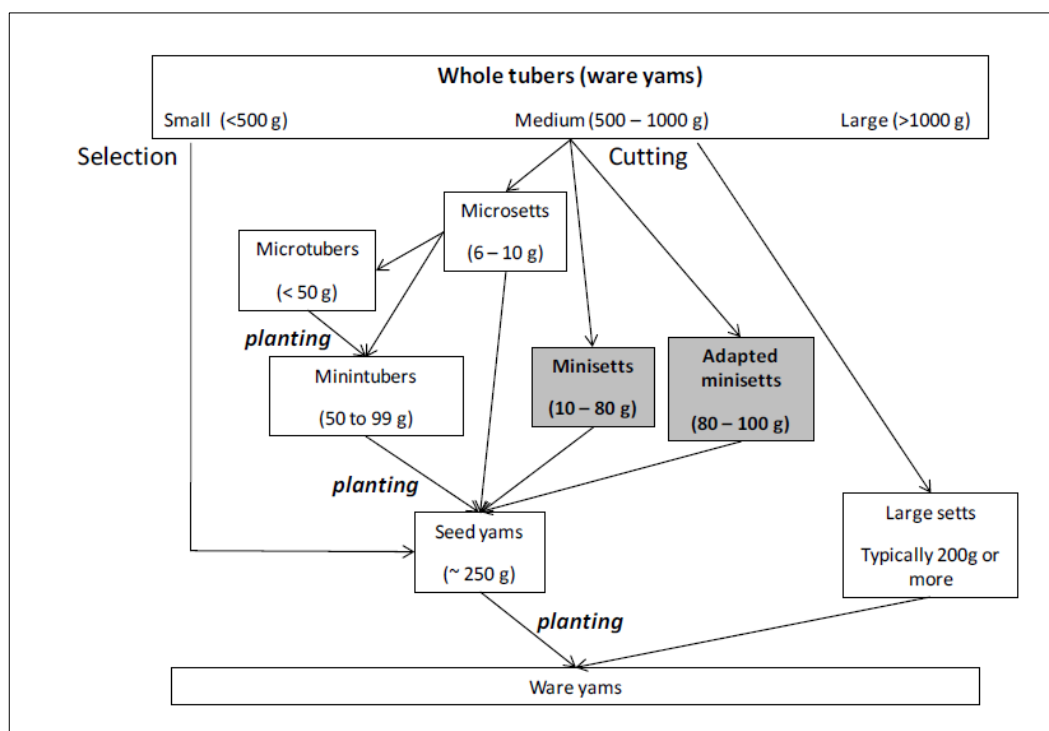


Figure 4.1. Various approaches for reproducing yam (from Morse and McNamara 2015).

Planting yam as a sole crop is uncommon in Nigeria. In the humid forest zone, yam is frequently inter-planted with maize, vegetables, melon, cocoyam, cowpea, and cassava; whereas in the Guinea savannah zone, inter-crops may include sorghum and millet (Orkwor and Asadu 1998). Many varieties of white guinea yams (*D. rotundata*) are grown, with water yams (*D. alata*) coming in second.

2.2 MARKET IMPORTANCE OF YAM FOR FARMERS

Yam is a vital crop, not only to the domestic market but also for export. The Central Bank of Nigeria (1998, cited in Bamire and Amujoyegbe 2005) reported that yams earn an average of 32% of farmers' gross income derived from arable crops. Yams are processed in many ways, including pounded yam (from *D. rotundata*, and sometimes, *D. cayenensis*), boiled, roasted or grilled yam, fried yam slices and yam balls, mashed yam, and yam chips and flakes (Bamire and Amujoyegbe 2005). Fresh yam tubers are also peeled, chipped, dried, and milled into flour, which is then cooked in boiling water and turned into a thick paste called amala in Western Nigeria (Oguntade et al. 2010).

2.3 GENERAL SEED SECTOR CHARACTERISTICS

Yams are usually vegetatively propagated by planting pieces of tuber. Before the miniset technology, large ware yam tubers from previous seasons were divided into pieces called cut setts, and these were planted in the new season. This tends to increase disease in the planting materials and in the field. Moreover, the planting material is bulky and expensive. Seed yams can also be produced through the traditional system in which the yams are milked after the first six months of planting and left in the soil to allow the seed tubers to form. Milking is the practice of removing a developed yam tuber, and then cutting off the topmost part and replanting it back into the ground. In "partial sectioning" (cutting a whole ware yam tuber into four chunks) (Orkwor and Asadu 1998), farmers bury the tuber piece in fertile soil or a compost mixture. The farmers wait for the sprout to emerge, and then transplant it.

To make seed cheaper, the YMT was developed in the 1970s by the National Root Crop Research Institute (NRCRI), Abia State, Nigeria, and IITA (IITA 2013). This was later modified and relabeled as the AYMT by IITA and Diocesan Development Services (DDS), Kogi State, Nigeria (2003–2006). The AYMT was designed to address the concerns of farmers who rejected YMT because it involves various new tasks that add to the labor demand, and to address concerns with germination of small minisetts of about 25 g.

2.4 TRENDS, DEVELOPMENTS, ONGOING CHANGE OF CONTEXT

Brief history of change from YMT to AYMT. YMT, designed for rapid, high-volume seed yam production (Orkwor and Asadu 1998), involves cutting a ware yam into many setts of about 25 g each, dusted with pesticide and wood ash, and planted in a nursery bed for pre-sprouting. In AYMT, cut setts of about 100–150 g (later reduced to about 80 g) are dipped into a mild cocktail of chemicals (fungicide + insecticide; 100 mg of mancozeb, 70 ml of Basudin, and 10 l of water) for 5–10 min, air dried at room temperature under shade, and planted directly into the fields on the following day (McNamara et al. 2012; see Figure 4.1).

Farmers rejected YMT for two reasons: the high labor costs of planting the setts in a nursery prior to field planting, and the pieces were so small that many died (Okoli 1986). In the DFID project, the YMT was modified to become AYMT, by increasing the size of the minisetts to about 80–100 g, combined with a chemical treatment to protect from pests and diseases and planting directly in the field, bypassing pre-planting in nurseries (Table 4.1; McNamara 2012). Because of the simplicity, cost-effectiveness (labor savings), and high germination rate, AYMT was well appreciated by the farmers and is fast emerging as the choice technique for seed yam production in West Africa.

Table 4.1. Features of the different yam seed production methods

	YMT	AYMT	Partial sectioning	Traditional methods
Designed by	NRCRI/IITA	NRI/IITA/DDS	NRCRI	Farmers
Sett weight	About 25 g	80–120 g	Whole tuber partially sectioned	Whole tuber of about 200–500 g**
Chemical	Pesticide & wood ash	Insecticide & fungicide	Not treated	Wood ash
Application	Dust	Water-based dip	-	Dust
Mode of planting	Nursery for pre-sprouting	Directly in the field	Whole in fertile soil or compost	Directly in the field
Multiplication ratio (seed:seed)	1:30	1:4–1:10*	1:10–1:16	1:1–1:8**
Constraints	Labor intensive, high cost of production	Cost of chemicals, perceived residual effect of chemicals	Labor intensive, requires skill, pests and diseases	Pests and diseases

Source: Coyne et al. 2010; Kenyon 2006; McNamara et al. 2012; Orkwor and Asadu 1998.

*Depending on the size of source yam.

** The traditional method is based on the use of whole tuber, while YMT and AYMT are setts.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 Before the intervention

The purpose of this project was to identify the best method (practicable and economical) from various seed yam technologies already developed, and to share the technology through demonstrations and other methods among seed producers in Nigeria and across West Africa.

Chikwendu et al. (1995) showed that although 78.8% of farmers in the eastern forest zone of Nigeria were aware of YMT, only 48.8% had actually tried it. Agbaje and Oyegbami (2005) found that only 33% of farmers adopted the technology in southwest Nigeria, despite 60% of the farmers having received information from the agricultural development program in their states. A DFID project final technical report also suggested that the rate of adoption was low (Kenyon 2006).

Farmers may produce seed yams to sell, to plant, or both. Most farmers sell seed yams only after they have enough to plant their own fields. West African farmers customarily make setts as planting material by cutting ware yam of about 1.2 kg into three plantable setts, each weighing about 400 g. It is also common for farmers to treat their setts with wood ash. Traditionally, farmers milk their yams to produce seeds (Philips et al. 2013). It is productive since for every milked tuber the remaining plant will generate five seed yam tubers (Ibana et al. 2012; Ikeorgu and Okonkwo 2010). That this functional practice exists may account for the low adoption of the YMT.

Men do most of the work in growing seed yams, which requires substantial energy and time (Oguntade et al. 2010); women are mostly involved in selling the seed yam. Most of the women who produce seed yams hire male laborers.

The baseline survey for this project showed that very few of the farmers were using the YMT. In Ekiti, both milking and cutting setts were used, whereas the farmers in Kogi often bought their planting materials. Most of the Ekiti HH believed that their home-grown planting materials were better than those on the market, whereas the HH in Kogi believed the opposite. Despite this, most farmers in both regions who had participated in the project were enthusiastic about growing more seed yams both for their own use and for sale.

3.1.2 What changed as a result of the intervention

The project developed simple written materials about pests and diseases and also explained step-by-step how to produce clean seed yams. These have become popular with the individuals and groups who received them. Several groups adapted the materials to their own needs and disseminated them. Figure 4.2 shows the steps of the (older) YMT. The AYMT involves cutting the yams into large pieces (about 80 g), dipping them in insecticide, and then air drying them and planting them directly into the yam mounds in the field the next day. This avoids the labor costs of making the seedbed to pre-sprout the yam. However, YMT required too much labor and had a low establishment rate in the field. On the other hand, AYMT had a lower multiplication ratio of seed than YMT, but was less work (e.g., without the pre-sprouting step) and had a better on-farm establishment rate.

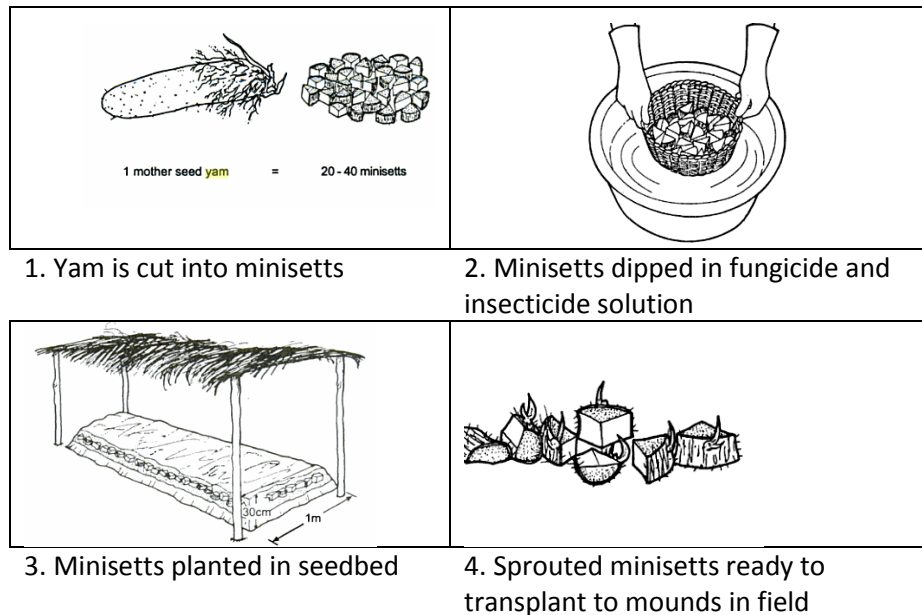


Figure 4.2. Steps of producing yam minisetts. Stage 3 in the figure is often required for YMT but not for AYMT. Source: Adapted from Otoo et al. 2001.

The project has also stimulated stakeholders to lobby the Nigerian Government for a Presidential Initiative to support improved and healthy seed yam production in Nigeria, to safeguard the future of the crop and for food security in Nigeria and West Africa.

Farmers already have simple techniques for producing their own good quality seed yams. But growers regard these as risky and requiring a large cash investment at times of the year when most of them have little money. However, farmers believed that productivity and farm income could be improved if the supply of good quality seed yams could be increased.

The project outputs suggested that there is a potential to grow seed yam commercially in Nigeria.

3.2 AFFORDABILITY OF THE NEW SEED YAM

The project confirmed that good, healthy seed yams are expensive and in short supply, but that the lack of HH capital and labor are major constraints to yam production. Before this project, two moderately virus-resistant *D. rotundata* varieties (TDr 89/02665 and TDr 98/00804) were multiplied and distributed free of charge to farmers for on-farm testing and subsequently used to produce healthy seed yams. Farmers were willing to produce their own seed yams by adapting technology they learned from this project. They were also willing to buy seed yams to make up for the ones they were unable to produce. The unreliable supply of appropriate, authentic fungicides and insecticides for treating planting pieces is a major constraint to the seed yam production system being promoted by the project.

About 400 farmers in Kogi State received credit from Gorta, an Irish organization, in collaboration with DDS to produce good quality seed yams as part of hh livelihood studies. This reduced production costs and encouraged increased seed production.

The livelihoods/cost-benefit analysis used during this DFID project indicated that farmers can produce their own healthy seed yams in an economically sustainable manner by adapting techniques identified in earlier projects. The techniques could be improved and adapted to the needs of small-scale yam growers elsewhere in Nigeria by using the information gained from studying the methods of commercial seed yam growers (Kenyon 2006).

Prior to this project, there was no literature on the opportunity costs of producing healthy seed yam. The technique introduced in this project produced seed yams that were both healthier and up to six times higher yielding than farmers' own methods (IITA 2013). Commercial seed yam, produced with AYMT, could be a viable option for smallholder farmers, with gross margins potentially double those of growing yam as a food crop.



Virus is a major problem in yam.
Photo by IITA

Seed yams versus ware yams. Because the cost of seed yam is 20–40% of the total production cost, farmers often use cut setts to reduce the seed yam to 10% of production costs (Philips et al. 2013). Nwauzor (2007) found that producing commercial seed yams through YMT is more profitable than through ware yam.

Different categories of farmers. In consultation with project staff and other stakeholders, the project created a series of yam pest and disease identification sheets and posters, which were distributed among the project partners in 2003 and 2004 for evaluation. Revised versions with minor modifications were printed and distributed in late 2003 through 2005. A simple guide to the pre-planting treatment of cut setts with the fungicide and insecticide cocktail was produced in late 2004; after a brief evaluation, a revised version was distributed. Templates for the identification sheets, posters, and the guide were sent to agricultural research institutes across West Africa. The materials were translated into French for the francophone countries. Field days and demonstration events were also held across the major yam-producing states with practical training sessions for participants including extension agents, farmers, and journalists.

3.3 SEED QUALITY

3.3.1 Before the intervention

Nematodes (*Scutellonema bradys* and *Meloidogyne* spp.), often interacting with fungi (e.g., *Botryodiplodia* sp., *Fusarium* sp.) and bacteria (e.g., *Erwinia* sp.), attack tubers of susceptible varieties in the field and continue their damage during storage, leading to loss of food quality and quantity as well as of planting materials (Emehute et al. 1998). Insect pests surviving on the tuber—for example, termites (*Amitermes* sp.), tuber moth (*Euzopherodes vapidella*), mealybug (*Planococcus* spp., *Phenacoccus* spp.), scale insect (*Aspidiella hartii*), and tuber beetles (*Heteroligus* spp., *Prionorcytes* spp.)—damage the planting materials after planting and during storage (ibid.), causing large losses.

Rot, caused by various pathogens, is the most common cause of yam tuber spoilage (Ajayi and Olorundare 2014). Healthy looking yams may harbor disease deep within the tubers, suggesting that many infections may start before harvest and may even stem from the original planting material (Rees and Bancroft 2003).

Farmers manage disease in storage by removing rotten tubers, breaking sprouts, curing damaged tubers before storage, and applying chemicals. But the farmers' method of adding wood ash did not effectively reduce losses.

Two *D. rotundata* accessions (TDr 89/02665, TDr 98/00804) with apparent partial resistance to yam mosaic virus in Nigeria were collected from IITA and multiplied to produce planting material. These were distributed to farmers participating in the on-farm trial.



Yam damaged by nematode.
Photo by IITA

3.3.2 What changed as a result of the intervention

The minisetts treated with both fungicide and insecticide/nematicide produced more and heavier tubers than the other treatments. The ware yams produced from the pesticide-treated setts were of higher quality and weight, and they stored well over the dry season, with less rotting and less drying than the ware yams from untreated setts (Claudius-Cole et al. 2004).

4. Seed producers and seed availability

4.1 THE MODEL

The model used during this project was AYMT. The main objective of the project was to promote knowledge on yam pests and diseases and production of healthy seed yam by evaluating different crop protection practices to improve seed yam health and availability in project areas in Nigeria, and also suitable for the yam-growing belt of West Africa. The project therefore intended to provide technology that resource-poor farmers could learn and use to produce healthy seed yams. The model adopted was a simple method, which showcased the new techniques on farmers' trial plots and on-station to improve farmers' awareness of AYMT. The model was based on an improved understanding of farmer knowledge and practices and on producing appropriate extension materials.

Most farmers know about miniset technology; however, very few have used it for seed yam production (Agbaje and Oyegbami 2005). Introducing a new version of a technology without first finding out why farmers did not adopt the last version could doom the project from the outset. The intervention did not seek to identify and involve commercial seed yam growers in the project, or consider the varieties demanded by the ware yam producers. The intervention did facilitate the establishment of a National Seed Yam Growers Association, which was mandated to support growers and extension agents, and to serve as a platform for influencing regional and national policy for yam production and seed supply. Women were not specifically sought out because most seed yam farmers are men.

Scaling up. This DFID seed yam project and previous interventions with miniset technology suggest that scaling up would require:

- 1) More attention to the whole value chain, especially for accessing funds for the resource-poor farmers who produce seed yams.
- 2) Cost-benefit analyses, including of opportunity costs, under different conditions to determine pricing margins and overall business feasibility. There are conflicting cost-benefit analyses for producing seed yam in different parts of the country, but no data were available for the AYMT.
- 3) Explore other uses of the seed yams (e.g., ways to use unsold ones).
- 4) Synchronizing the breaking of dormancy with time of planting to reduce postharvest loss.
- 5) Depleting soil fertility.
- 6) Access to formal seed markets.
- 7) Quality control development within the seed yam value chain.
- 8) Uniform size of seed yams.

Some of these issues were addressed through another project, “Upscaling Sustainable Clean Seed Yam Systems for Small Scale Growers in Nigeria.” This 2005–2006 project aimed to gain a better understanding of the systems and economics of seed yam production and further evaluate, demonstrate, and promote the systems developed in earlier projects. It established 16 demonstration and training plots in Ekiti and Kogi states, and 15 in four other states (Abuja, Rivers, Oyo, and Kwara), with farmers using their own planting material. In Kogi State alone, the AYMT was promoted to about 250,000 people through the DDS Farmer Council program. The technology was also promoted in the Federal Capital Territory of Abuja, through a regular TV program (IITA 2013).

A highly significant gain was made in a project “Yam Improvement for Income and Food Security in West Africa (YIISFWA),” funded by the Bill and Melinda Gates Foundation (BMGF), with a scaling out of the yam seed system developed in this DFID project. The successes of YIISFWA were a result of the involvement of partners from the DFID project, especially DDS and MSHR (Missionary Sisters of Holy Rosary). YIISFWA is creating FGs and promoting AYMT directly to them by training. Research-into-Use, another DFID project, also extended the technology designed by this intervention to another 250 farming HH in Igalaland, and to other NGOs outside of Igalaland. Research-into-Use provided funding as start-up credit, and introduced the technology to youth.

Various projects are promoting the technology, with the assumption that farmers are adopting it. The different interventions extending the technology designed in this project have helped to overcome bottlenecks to farmers’ adoption of AYMT. Making funds available to resource-poor farmers will encourage adoption. AYMT is also being promoted in Ghana.

Market intelligence. Traditionally, yams are grown using whole tubers; partial sectioning doubled the multiplication rate, but required much labor for the repeated examination of planted sectioned tuber and digging them up to remove sprouts for transplanting (Orkwor and Asadu 1998). This technique is appropriate for research and must have led to the designing of YMT.

Farmers have rarely adopted minisetts (YMT), because they are poorly known and because of high losses, mostly from pests and diseases, and because the sprouted setts are delicate in the nursery. The setts are costly to produce and require a lot of labor to follow up staggered sprouting and transplanting (ibid.).

AYMT curbs minisett losses with pesticides, avoids pre-sprouting in wood ash, thereby eliminating the need for making a nursery, which discouraged farmers from adopting YMT. AYMT improves the germination rate and reduces the loss of seed yam. This might convince farmers to adopt the technique. This project is all about promoting the technique, exploring the scaling-up potential, while understanding the seed quality.

4.2 BENEFITS FOR FARMERS

Advantages:

- 1) Farmers can use their own seed
- 2) AYMT enables farmers to plant 5–10 times more yams than traditional methods
- 3) Better and higher yields than when produced through their traditional methods
- 4) Tubers produced using AYMT have less pest and disease infection

- 5) It offers a more profitable enterprise for farmers and improved livelihoods.

Disadvantages:

- 1) High labor cost
- 2) Technique depends on chemicals that are not always available
- 3) Seed yams derived from AYMT are not resistant to pests and disease, and thus good management is key to realizing all potential benefits
- 4) Care is required to prevent poisoning humans or environmental contamination, and to ensure the safe disposal of excess chemicals and packages. This method is not suitable for organic farming.

4.3 QUALITY ASSURANCE AND REGULATION

The quality of the seed yams produced is dependent on the integrity of the grower. Most quality aspects can be guaranteed through proper training, assuming that the growers adhere to good management practices, including the use of recommended pesticides. Minisetts used for propagation should be adequately treated with the pesticide dip. The source of the ware yams and their growth history from the previous season could help determine their disease and pest status.

Seed yam quality standards have been published by the Economic Community of West African States (ECOWAS 2008) after the project duration for formal sector, and guidelines have been detailed for quality declared planting material (QDPM) (FAO 2010); however, there was no evidence of implementation. Nonetheless, AYMT is suitable for adoption to produced seed yam in both the formal and informal sectors and can improve compliance with pest and disease thresholds set forth in the regulations. There were no specific standards for ware yam quality or for the export of ware yam in Nigeria.

Subsequent efforts by the scaling-up projects will show whether AYMT was a valid idea or not, and may improve the technology.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

Varietal purity, viability, weight, and freedom from pests and diseases are some of the criteria used to determine the standard quality for seed yam (Aighewi et al. 2014). Seed yams available to farmers for ware yam production are subdivided into three major categories: farmer-save seed, QDPM, and certified seeds.

Farmer-saved seeds are the reserve from the previous season, and their quality is determined by the farmers' standard and experience. QDPM is generated by a farmer or group of farmers complying with certain minimum standards (FAO 2008). At present, there is no official or autonomous program overseeing QDPM in Nigeria. The QDPM concept for seed yam production emerged after the DFID

project ended. Certified seeds are produced in formal seed systems with the necessary management practices in place and the relevant agencies to follow the rules and regulations established by ECOWAS (2008; Aighewi et al. 2014). There is no evidence of certified seed production in the past. However, efforts are being made in the Yam Improvement for Income and Food Security in West Africa (YIIFSWA) project to stimulate certified seed yam production in Nigeria and Ghana (Maroya et al. 2014).

Policy changes. There was no policy governing seed yam production in Nigeria prior to this intervention. One of the achievements of the intervention was to establish a network of stakeholders who have a strong interest in improving the seed yam industry. The network has started to make contact with the government for policy formulation that will encourage growers. The YIIFSWA project is building on the earlier success of DFID projects and laying the foundation to strengthen production of healthy seed yams in both formal and informal sectors. Existing thresholds for pests and diseases have been revised to suit prevailing conditions, and efforts are also being made to promote QDPM for seed yam production with regulatory backup (Maroya et al. 2014).

5.2 SEED HEALTH AND QUALITY

Prior to this intervention, there were no practical guides in place to regulate the standard of seed yam quality. After the project, ECOWAS published rules (ECOWAS Regulation No. C/REG.4/05/2008) governing quality control, certification, and marketing of seeds that set the standard for certified seed yam. Appropriate seed quality regulation will enhance production and marketability of high-quality seed yam nationally and regionally, and ultimately help to further open the export market.

Formally certifying AYMT may not actually be practical as seed certification includes several other parameters (e.g., plant spacing, varietal purity, etc.) (ECOWAS 2008). However, AYMT contributes to the seed producers' requirement to produce seed yams within stipulated thresholds for pests and diseases.

Since all the planting materials were derived from within Nigeria, there were no quarantine issues.

6. Seed multiplication tools and techniques

What works best? A study by McNamara et al. (2012) in Edeke, Kogi State, concluded that the cost of producing seed yam in 1 ha, using minisetts, varied wildly from N0.9 million (\$5,800) to N5.3 million (\$34,000). Few of the studies specified in detail the technology used. A study by Oguntade et al. (2010) found the cost to be far lower: N150,500 (\$970) per hectare.

It is more profitable to produce seed yam with AYMT than with traditional methods (IITA 2013). The costs, including the expense of buying genuine agrochemicals (as opposed to fake agrochemicals), may exclude resource-poor farmers from this technology.

Costs. The economic environment is dynamic, with production cost differing from one place to another. Prices of planting materials and inputs such as stakes are different from one place to another as well. Transportation costs are influenced by distance and the state of the roads. Production costs can also depend on the variety of yam planted, the season of the year, the market outlet, and the quality and sizes of the seed yam (Table 4.2). Planting density chosen by the growers also affects cost and production (McNamara et al. 2012).

Table 4.2. Yam tuber classifications

Yam tubers	Category
Ware yams	>1 kg
Seed yams (Grade 1)	250 g–1 kg
Seed yams (Grade 2)	100–249 g
Mini-seed yams, now minitubers	50–99 g
Micro-seed yams, now microtubers	50 g

Source: Ogbonna et al. (2011)

7. Lessons

Since farmers had already rejected YMT (Agbaje and Oyegbami 2005), the adapted version (AYMT), developed and employed in this project, should have involved more farmers in further experiments with the technology. Various projects later shared AYMT with other farmers, so it must have had its virtues. The project assumed that farmers would be able to produce seed yams in commercial quantity without credit. This was unrealistic, as many farmers already needed credit to produce seed. This observation must have informed the project decision to involve Gorta (Self Help Africa) for funds in the subsequent scaling-out project.

Key criteria for success identified during the intervention were:

- 1) Good integration among the stakeholders (farmers, extension workers, NGOs, donor agency, journalists, etc.).
- 2) Connecting seed yam growers with the Gorta for credit and the Dizengoff (agricultural inputs company) for consistent and reliable chemicals supply. This was important because the farmers cited the cost of the chemicals and their lack of availability as a limitation. Dizengoff Agriculture Nigeria is a reputable agro-input company.
- 3) Dynamic farmers participated in on-farm trials.
- 4) Creating a sense of ownership for the seed yam farmers.
- 5) Creating platform for lobbying policymakers.

References cited

- Agbaje GO, Oyegbami A. 2005. Survey on the adoption of yam miniset technology in South-Western Nigeria. *Journal of Food Agriculture and Environment* 3(2):134–137.
- Aighewi BA, Maroya NG, Asiedu R. 2014. Seed yam production from minisets: A training manual. Ibadan: IITA, 40 pp.

- Ajayi AO, Olorundare SD. 2014. Bacterial and fungal species associated with yam (*Dioscorea rotundata*) rot at Akungba-Akoko, Ondo State of Nigeria. *Applied Science Research Journal* 2(2):12–28.
- Asare-Bediako E, Showwenmimo FA, Opoku-Asiama Y, Amewowor DHKA. 2007. Improving sprouting ability of white yam minisetts (*Dioscorea alata* Poir) var. Pona and Dente using different disinfectants and protectants in sterilised saw dust. *Journal of Applied Science* 7(20):3131–3134.
- Bamire AS, Amujoyegbe BJ. 2005. Economic analysis of land improvement techniques in smallholder yam-based production systems in the agro-ecological zones of southwestern Nigeria. *Journal of Human Ecology* 18(1):1–12.
- Bridge J. 1982. Nematodes of yams. In: Miege J, Lyonga SN, eds. *Yams/Ignames*. Oxford: Oxford University Press. p. 253–264.
- Chikwendu DO, Chinaka CC, Omotayo AM. 1995. Adoption of miniset technique of seed yams production by farmers in the eastern forest zone of Nigeria. *Discovery and Innovation* 7:367–375.
- Claudius-Cole AO, Coyne D, Kenyon L, Ayodele M, McNamara N, Morse S. 2004. Seed yam production systems: Assessment of various pre-plant treatments of setts for production of nematode free material. Presented at the First West and Central African Nematology Meeting held in Douala, Cameroon, 8–10 November 2004.
- Coyne D, Claudius-Cole A, Kikuno H. 2010. SP-IPM Technical Innovation Brief 7. *Sowing the Seeds of Better Yam*. Ibadan: IITA.
- ECOWAS. 2008. Regulation C/REG.4/05/2008 on the harmonization of the rules governing quality control, certification and marketing of plant seeds and seedlings in ECOWAS region. VI Ordinary Session of the Council of Ministers, 17–18 May 2008, Abuja, Nigeria. 30 pp.
- Emehute JKU, Ikotun T, Nwauzor EC, Nwokocha HN. 1998. Crop protection. In: Orkwor GC, Asiedu R, Ekanayake IJ, eds. *Food Yams: Advances in Research*. Ibadan: IITA. p. 141–186.
- FAO. 2010. Quality declared planting material: Protocols and standards for vegetatively propagated crop. *FAO Plant Production and Protection Paper* 195. Rome: FAO. pp. 97–108.
- Ibana S, Coyne D, Claudius-Cole A, McNamara N, Morse S. 2012. Economic analysis of commercial seed yam production systems in the sub-humid ecologies of the River Niger. *Journal of Crop Improvement* 26(1):22–38.
- FAO. 2014. *FAO Corporate Document Repository: Storage and Processing of Roots and Tubers in the Tropics*. (Available from <http://www.fao.org/docrep/x5415e/x5415e01.htm>) (Accessed on 2 October 2014)
- Ibana S, Odoemena B, Akintola JO, Ihedioha D, Okoli P. 2009. Constraints to the delivery of clean seed yams in the lowland sub-humid tropics of Nigeria: The supply chain approach. *African Journal of Agricultural Research* 4(4):321–329.
- IITA. 2013 (February). “Healthy yam seed production.” *European Initiative on Agriculture Research for Development*. p. 1–6.

- Ikeorgu JG, Okonkwo CC. 2010. Varietal response of seven new hybrid yam varieties to minituber production using the microsett technique. *African Journal of Root and Tuber Crops* 8(1):62–65.
- Kambaska KB, Santilata S, Trinanth M, Debashrita P. 2009. Response of vine cuttings to rooting in different months in three *Dioscorea* species. *Journal of Natural Sciences* 7(12):48–51.
- Kenyon L. 2005. Evaluation and promotion of crop protection practices for “clean” seed yam production systems in Central Nigeria (R8278). Final project technical report. Crop Protection Programme, NR International.
- Kenyon L. 2006. Up-scaling sustainable “clean” seed yam production systems for small scale growers in Nigeria. DFID Crop Protection Programme, Final technical report, Project R8416. Chatham, Kent, UK: Natural Resources Institute, University of Greenwich. 19 pp.
- Kikuno H, Muamba K, Shiwachi H, Onjo M, Asiedu R. 2006. Minituber production of white yam (*D. rotundata*) using vines. *Japanese Journal of Tropical Agriculture* 50 extra issue, 1:1–3.
- Kleih U, Phillips D, Mignouna D, Ogbonna M, Siwoku B. 2012. Yam Improvement for Income and Food Security in West Africa (YIIFSWA): Nigeria – Scoping yam value chain analysis. YIIFSWA Project Document. Ibadan, Nigeria: IITA. 58 pp.
- Maroya N, Asiedu R, Kumar PL, Mignouna D, Lopez-Montes A, Kleih U, Phillips D, Ikeorgu J, Otoo E. 2014. Yam improvement for income and food security in West Africa: Effectiveness of a multi-disciplinary and multi-institutional team-work. *Journal of Root Crops* 40(1):85–92.
- McNamara N, Morse S, Ugbe UP, Coyne D, Claudius-Cole A. 2012. Facilitating healthy seed yam entrepreneurship in the Niger River system in Nigeria: The value of ‘Research-Into-Use’. *Outlook on Agriculture* 41(4):257–263.
- McNamara N, Morse S. 2014. Working with farmers to produce clean seed yams. YIIFSWA Working Paper Series No. 5. Yam Improvement for Income and Food Security in West Africa. Ibadan: IITA. 48 pp.
- Migap JP, Audu F. 2012. Empirical study on yam cultivation and economic development of Taraba State: Case study of Wukari local government area. *Journal of Business and Organizational Development* 4:32–53.
- Morse S, McNamara N. 2015. The adapted yam minisett technique for producing clean seed yams (*Dioscorea rotundata*): Agronomic performance and varietal differences under farmer-managed conditions in Nigeria. *Experimental Agriculture* 51:467–482.
- Morse S, McNamara N, Acholo M. 2009. Potential for clean seed yam minisett production by resource-poor farmers in the middle-belt of Nigeria. *Journal of Agricultural Science* 147(5):589–600.
- Nwuzor BA. 2007. Comparative economic analysis of yam minisett and ware yam production in Abakaliki local government area, of Ebony State, Nigeria. *International Journal of Agriculture and Food Systems* 1(1):18–22.

- Ogbonna MC, Korieocha DS, Onyenobi VO, Njoku SC. 2011. Profitability of minituber seed yam production technique in south east agro-ecological zone: Evidence from Abia State, Nigeria. *Journal of Agriculture and Social Research* 11(2):113–119.
- Oguntade AE, Thomson OA, Ige T. 2010. Economics of seed yam production using miniset technique in Oyo State, Nigeria *Field Actions Science Reports* 4:1–5.
- Orkwor GC, Asadu CLA. 1998. Agronomy. In: Orkwor GC, Asiedu R, Ekanayake IJ, eds. *Food Yams: Advances in Research*. Ibadan: NRCRI/IITA. p. 105–141.
- Otoo JA, Okoli OO, Ilona P. 2001. *Improved Production of Yam Seed*. Ibadan: IITA. 21 pp.
- Otoo JA, Osiru SO, Ng SY, Hahn SK. 1987. *Improved Technology for Seed Yam Production*. 2nd ed. Ibadan: IITA. 66 pp.
- Rees D, Bancroft R. 2003. Development of integrated protocols to safeguard the quality of fresh yams. Final Technical Report, 1 February 2000–31 March 2003, Natural Resources Institute, University of Greenwich, UK. 125 pp.

CHAPTER 5

Bananas and plantains in Ghana: TARGET

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Abstract

Plantain has a low natural multiplication rate, making it difficult to expand production. Also, many pests and diseases inhibit optimum production. Between 2003 and 2005, Bioversity International and IITA partnered with the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR) of Ghana and World Vision to distribute new plantain and banana cultivars for on-farm testing. Over 2,000 farmers planted small plots of four new hybrids and were trained in rapid macropropagation techniques for clean seed multiplication and other improved agronomic practices.

After initial hesitation, farmers embraced the unfamiliar planting material, particularly after observing the vigor and healthy foliage of some of the hybrids. Rapid multiplication technologies were transferred as part of a technology package, including marketing, improved production, and pest management. Changes were also introduced for the postharvest handling (cooking duration) of the fruits. Rapid multiplication continues to be used in Ghana, promoted mostly by extension services and by CRI.

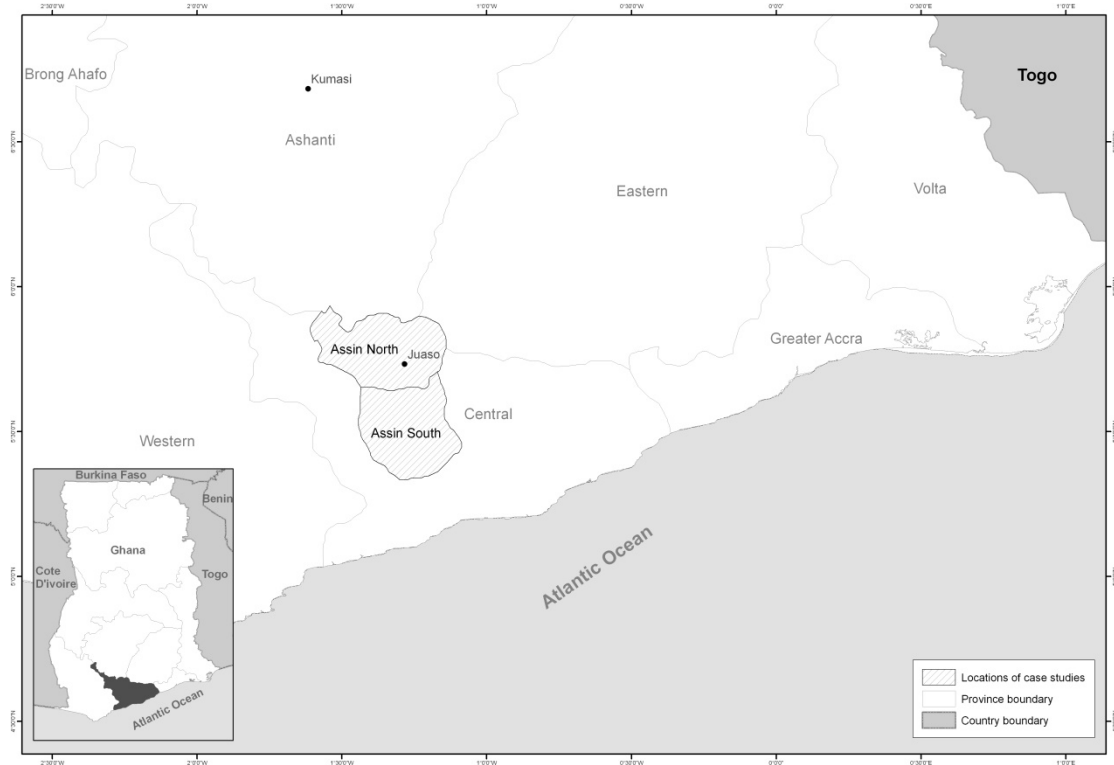
Rationale

Bananas and plantains (*Musa* spp.) are major staple crops in Ghana, contributing to HH food security and rural incomes. Production is threatened by pests and diseases, notably black Sigatoka (*Mycosphaerella fijiensis*), yellow Sigatoka (*M. musicola*), nematodes, and weevils. New high-yielding hybrids with resistance to Sigatoka and other pests and diseases have shown promising results in research stations and farmers' fields. Experience from other countries shows that where efficient plant multiplication systems are in place, adoption has followed. In line with these observations, it was concluded that a supply of planting material would help farmers to rapidly test and adopt these new varieties.

1. The intervention

TARGET was a technology transfer project that aimed to boost income and food security through the dissemination of high-yielding, disease-resistant hybrids. The project trained farmers and extension workers on low-cost methods to multiply planting materials and on improved production and marketing

methods, including postharvest technologies. This case study reports on the efforts concerning planting material (new hybrids and multiplication methodologies).



Theory of change

If productive, new banana and plantain varieties were shared with farmers who had been trained in the benefits of the varieties and how to manage them, farmers would reproduce the varieties on their own and share them with other villagers. Even after the project ended, farmers would continue to use the technologies to reproduce the crop and to manage pests and diseases.

Scaling up

The new hybrids, pest-management, and postharvest technologies had been previously tested and found to be beneficial for farmers. The 2-year TARGET project aimed to disseminate these technologies on a larger scale, in four countries (Mozambique, Cameroon, Tanzania, and Ghana), with 4,000 farmers, each receiving four hybrids and training. This case study looks at the project in Ghana, where 887 farmers participated (500 in 2003, 387 in 2004). All farmers who received TC plantlets were to supply some suckers to the project after one year for cleaning and further distribution to new farmers.

Stakeholders of the seed system intervention during the TARGET project:

- 1) Government agency: CRI of the CSIR;
- 2) NGO: World Vision Ghana (WVG)
- 3) Government agency: Ministry of Food and Agriculture (MoFA), provided extension officers
- 4) IITA; Bioversity International, which includes the International Transit Center, located at the Catholic University in Leuven, Belgium; Centre Africain de Recherches sur Bananiers et Plantains (CARBAP), which developed the hybrid CRBP-39 and was involved in the TARGET project in Cameroon; and the Fundación Hondureña de Investigación Agrícola (FHIA), which developed some of the hybrids, but was otherwise not involved in the project.
- 5) Private Seed Sector: Du Roi Laboratories, South Africa.



An extension officer admires a CRBP 39 sucker. This type of planting material can be slow and challenging to produce.
Photo by Beloved Mensah Dzomeku.

Framework: Ghana TARGET project

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiologic al age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
National research (CRI of the CSIR)	Received TC plantlets, hardened in nursery. Macro- propagation of plants	Distributed TC plantlets to farmers	TC plants donated free of charge	Trained extension officers & farmers; provided technical backstopping		
National research (MoFA)		Selected the sites and farmers to participate		MoFA extension officers lived in the farming communities, provided on farm training		
International research: IITA, Bioversity, CARBAP, FHIA		Provided virus indexed in- vitro cultures of selected hybrids to Du Roi Laboratories	Donated starter material of TC plantlets		Developed new hybrids (FHIA 21, FHIA 25, CRBP 39, BITA 3)	
Private seed sector: Du Roi Laboratories	Mass propagation of plantlets (4,000 of each hybrid for Ghana)		Donated TC plantlets			
NGO: WVG			Disbursement of project funds to MoFA extension officers			
Seed users/ farmers	Received free TC plantlets, and were asked to give back suckers for expansion of project		Asked to donate suckers produced by TC plantlets received free of charge	Received training in production, multiplication of clean seed and postharvest technologies	Received new hybrids	Received training in clean seed multiplicati on and pest managemen t

The TARGET project had an impact on all main functions within the banana seed system in Ghana (see Framework, above):

It attempted to increase the supply of planting materials (see section 3.1 Seed acquisition and accessibility of seed) through training in the use of rapid multiplication methods (macropropagation) and the import of TC plantlets.

It attempted to improve the sanitary quality of the planting materials available to farmers (see section 3.2 Seed quality) through provision of resistant hybrids and technologies that can clean infected suckers (paring) or provide clean planting materials (macropropagation methods, if carried out following standard protocol).

It influenced information and awareness through training in improved production methods, giving farmers better criteria for sucker selection.

The dissemination pathways of the planting materials were primarily managed by the project, or partially subsidized in combination with training of farmers and extension officers (e.g., building macropropagation chambers, importing the initial TC plantlets from South Africa). The goal was that farmers would eventually continue to disseminate the hybrids within their own community.

2. General context

2.1 FARMING SYSTEMS

Musa farming systems in Ghana includes both mixed cropping (85%) and mono-cropping (15%; Dzomeku et al. 2010a). Intercropping with cash crops such as cacao is common. Chemical inputs are used infrequently, and farmers use few if any specific soil fertility maintenance practices (Dankyi et al. 2007). Plantains are grown in 6 of 10 political regions in Ghana, in the humid forest and on sandy-loam soils. The TARGET project was carried out in 10 villages, in two districts (Assin North and Assin South) in the Central Region of Ghana (Table 5.1).

Table 5.1. Climate and soils of sites in Ghana

Village name	Altitude (masl)	Soil texture	No. of months <100 mm rainfall	Dry periods
Wurakese	167	Clay-loam	9	Dec-Feb
Dwendaama/kabekor /kenia/Dankor	147	Clay-loam	9	Dec-Feb
Nduaso	109	Clay-loam	9	Dec-Feb
Ninkyiso/Bereku	126	Clay- loam	9	Dec-Feb
Aworoso Camp	116	Clay- loam	9	Dec-Feb
Ayithey	117	Sandy-loam	9	Dec-Feb
Dorsi	126	Clay-loam	9	Dec-Feb
Jakai	123	Clay-loam	9	Dec-Feb
Andiembra	130	Clay-loam	9	Dec-Feb
Ongwa	No data	Clay-loam	No data	Dec-Feb

2.2 MARKET IMPORTANCE OF BANANAS AND PLANTAINS FOR FARMERS

In 2010 Ghana produced 1,870,000 t of plantains and bananas, becoming the fourth most important producer in West and Central Africa after Nigeria, Cameroon, and Ivory Coast. Ghana was the second most important producer of plantains, at 1,680,000 t, just after Nigeria (Lescot 2012). Plantains hold an important place in Ghanaian cuisine. They can be prepared as kelewele (fried and spicy), fufu (boiled and pounded with cassava or yam), ampesi (boiled whole), roasted when green or ripe, or as chips (fried green plantain). In addition, ropes and doormats are made from pseudostem fibers.

Transport infrastructure is generally well developed in Ghana, and most farmers indicate that traders visit their farms to buy produce (Dankyi et al. 2007). “Market queens” and designated middle-women dictate the prices, and buy bananas and plantains from the farmers to resell to the public. As there are few wholesalers, they can rapidly exchange information and agree on prices and the quantity allowed on the markets. New entrants may thus not be permitted to sell their produce if they do not belong to a specific market (Dzomeku et al. 2011). Both men and women are involved in production, yet it is mainly the women who process and market plantains. Between 1991 and 1992, 30% of female-headed HH cultivated plantain; 34% of plantain farmland was held by women, and women kept the revenue on 32% of plots where plantain is cultivated (Doss 2002).

When farmers were asked to rank constraints to plantain production, they cited lack of credit, weed pressure, disease pressure, and lack of labor, in that order (Dzomeku et al. 2011). Farmers also cited decreasing soil fertility, lack of good quality planting material, and marketing-related issues as major production constraints (Schill et al. 2000).

2.3 GENERAL SEED SECTOR CHARACTERISTICS

There was limited buying and selling of banana or plantain planting material, before or after the TARGET project. Conventional suckers of landraces are sold in heaps of 50 or 100 in local markets. Suckers are sold opportunistically, by farmers who are not specialized seed producers. The buyers are then responsible for transporting the suckers to the field. These suckers are varietal mixtures and may harbor pests and diseases. Farmers get most suckers from their own gardens. There is occasional demand for larger volumes of planting material from cocoa renovation projects or other agricultural initiatives.

2.4 TRENDS, DEVELOPMENTS, ONGOING CHANGE

Over the years, banana and plantain yields have increased, due not only to research and extension activities, but as well to expansion of cacao groves, where plantain is planted as shade. The mean annual growth rates for land area planted to plantain was 3.4% (from 1999–2001 to 2002–2004) and 2.5% (from 2005–2007 to 2008–2010). Most farmers are smallholders, with an average farm size of 0.8–1.6 ha (Dankyi et al. 2007). From 1980 to 2005, the average annual per capita consumption of plantains increased slightly, from 82.2 to 84.8 kg (Dankyi et al. 2007, cited in Dzomeku 2013).

Dankyi and colleagues (ibid.) found that most farmers had access to fairly good infrastructure, including phones, FM radio reception, passable roads, transportation, and electricity. The villages, however, lacked market information for produce prices and marketing trends (Dankyi et al. 2007).

Production is highly seasonal. When prices are high, farmers plant more, thereby increasing the amount in the glut period, when prices are low. Yet the market is too weakly articulated to absorb all of the production increase, which leads to excessive postharvest losses. This also affects the growth of agroindustry since there is a season of the year when raw material prices are very high. Ghana's agribusiness industry is relatively recent. In 2011, only five companies processed plantains into fufu flour. Plantain chips are produced mostly for the domestic market, with only minimal export, whereas fufu flour is exported for the African diaspora (Dzomeku et al. 2011).

Most of the population in Ghana now lives in urban areas, emphasizing the need and opportunity to improve delivery and processing pathways (UNDP 2013). Furthermore, European demand for plantain is considerable: 195,848 t were imported in 2010 (Lescot 2012). Ghana has the advantage of being closer to the European market than other plantain exporters like Colombia, Ecuador, Venezuela, and Costa Rica (Dzomeku et al. 2011).

3.1 Seed users

A survey of communities involved in the TARGET project, and adjacent nonparticipating communities, was carried out shortly after the TARGET project was completed (Dzomeku et al. 2008, 2010a, 2010b). Respondents were older (mean age: 47) and mostly full-time farmers, with little off-farm income. Most farmers worked their own family land. Many farmers intercropped plantain with other crops, including cocoa, cocoyam, vegetables, and cassava (Dzomeku et al. 2010a).

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 Before the intervention

Bananas and plantains are vegetatively propagated, and farmers will use suckers from an existing field to establish a new one. Sucker production is slow, particularly for plantains, and most varieties produce from two to five suckers in a year (Staver and Lescot 2015). Establishing a new field from an existing one may be limited by the availability of suckers; however, whether farmers experience a lack of planting material depends on the context and intention of the farmer. For example, there may be new market opportunities that call for an increase in production. Or the farmer may wish to establish a field using different varieties.

Lack of planting material is more likely to be a problem for a project than for farmers. For example, an intervention may focus on new hybrids, which need to be disseminated to farmers, or on demonstrating agronomic practices that allow farmers to tap into emerging or perceived market opportunities. Such projects would usually include a component on distributing planting material.

The TARGET project assumed that wide-scale adoption of new hybrids (see below under section 3.2) was hampered by a lack of availability of planting material. Indeed, the implementers saw that in countries where multiplication schemes are functional (e.g., Cuba, Tanzania), widespread adoption had been achieved. Over 90% of farmers in Uganda who had received training in multiplying clean planting material and in improved pest management now had improved plant vigor and production, with less yield loss due to plant breakage and toppling. In Ghana, benefits of \$475/ha had been observed,

compared with traditional practices, for farmers who adopted the technologies for three years (TARGET 2007).

Before the TARGET project, a few farmers in Ghana practiced the split corm technique to obtain planting materials. This technique increases the number of plants that can be obtained from a single sucker.

3.1.2 What changed as a result of the intervention

For the four hybrids (Table 5.2), each farmer received only three to five TC plantlets of each variety. The small number of plantlets allowed more farmers to participate but generated an unmet demand for planting material. If farmers want to expand their area, they can only increase to about 15–20 plants in the following season, using suckers alone. Therefore, the project trained farmers in multiplication methods and in how to build the macropropagation chambers (see also section 6 on multiplication methods).

Table 5.2. Hybrids and quantities disseminated during the TARGET project

Hybrid	Number of hybrid TC plantlets disseminated to 887 farmers
FHIA 21	8297
FHIA 25	2389
CRBP 39	1905
BITA 3	3691

Before the start of the TARGET project, farmers and consumers were presented with prepared fruits of the different hybrids for evaluation. Consumers' preferences and the project partners determined variety selection. For Ghana, FHIA-21, CRPB-39, FHIA-25, and BITA-3 were selected.

Characteristics of each variety (TARGET 2007):

- FHIA-21 is a French type plantain hybrid, which is commercial in many countries and resistant to black Sigatoka and races 1 and 2 of Fusarium wilt, but susceptible to the nematodes *Radopholus similis* and *Pratylenchus coffeae*. It can be eaten green (boiled, fried) or ripe (fried, baked); however, bruising and rapid ripening can be an issue. Bunch weights of FHIA 21 range from 22 to 35 kg with 120–150 fingers per bunch. It is a tall plant and may need propping to support the weight of the bunch.
- FHIA-25 is a hardy, semi-dwarf cooking banana variety that is highly resistant to black Sigatoka. It can be eaten green (boiled, fried) or made into juice. The strong plant supports bunches of more than 50 kg without propping. Since bunches are very large, they are best harvested one hand at a time, prolonging the green life of the rest of the bunch (up to 2 months). The fruits of the harvested bunch have a shorter green life than traditional varieties (10 days).

- BITA-3 is a starchy cooking banana, which is resistant to black Sigatoka and is virus tolerant. This hybrid yields from 5 to 52 kg per plant depending on the growing conditions. It can be eaten ripe (fried or raw) and is particularly appreciated in Nigeria in the dish dodo. This hybrid exhibits slow sucker development.
- CRBP-39 is a cooking-type banana and is resistant to black Sigatoka. It has good agronomic qualities and has been accepted by the people of Cameroon. The average bunch size of this hybrid is 22.3 kg with about 7.5 hands and 106 fingers.

During the TARGET project, training was given in two seed multiplication methods (split corm and macropropagation) and one cleaning (paring) technology. The technical details of these methods are described under Section 6: Multiplication tools and techniques.



Black Sigatoka symptoms on a plantain leaf. This is a major disease for bananas and plantains. Photo by Neil Palmer.

WVG established nurseries with farmers and MoFA extension officers, to produce clean planting materials in several communities. Materials such as polyethylene sheets and wheelbarrows were provided free of charge to set up nurseries. Suckers were also collected by WVG and MoFA from farmers and raised at the CRI nursery in the town of Assin Juaso, before distributing the clean, multiplied material back to the farmers. The Assin Juaso nursery continued multiplying and distributing suckers after the end of the TARGET project. WVG continued to provide resources to individual farmers who wanted to multiply suckers to distribute to other farmers. WVG built a propagation chamber for large-scale production of planting materials. During two sessions, 15 MoFA extension workers and WVG staff were trained on rapid multiplication. They also learned how to identify the new varieties.

The impact of the training of motivated extension officers was important, as they later set up demonstrations and taught farmers in additional regions (Ashanti, Western Region, Central Region) and they propagated and disseminated improved varieties to farmers. At Ejura in the Ashanti Region, WVG established a germplasm farm, or mother garden, of the improved plantain and banana varieties. A similar farm was also established at Assin Fosu with a mechanized sprinkler system for dry season irrigation so that plantlets could be produced throughout the year. WVG also established a clonal garden on their compound for multiplication of suckers. It is not known if these multiplication centers continued to exist after the TARGET project ended.

A survey in the TARGET project area observed that the split-corm technique was widely used, also by non-participants (Dzomeku et al. 2010a). The macropropagation technique and paring, however, were used mostly by the participants. Macro-propagation was the least adopted technique during the

TARGET project, probably because it requires specific skills, and a large investment in a high humidity chamber, nursery bags, and a shaded hardening nursery.

All technologies were tested in the participating communities; adoption rates were high, except for macropropagation (Dzomeku et al. 2010a). Extension offices were important for teaching the technologies to participating farmers, who then shared the ideas with other farmers in their networks.

Farmers continued using the multiplication activities, notably macropropagation, after the end of the project (BM Dzomeku, pers. comm. 2016). There are no market places in Ghana catering specifically to planting materials. However, a few farmers are practicing the technology on a modest scale. Plantains produce few suckers, and acquiring clean plantain planting material continues to be a challenge for farmers, particularly at the start of the rainy season (planting season). Suckers are often scarce following the long dry season.

There are two reasons why farmers are investing little in rapid multiplication as a business, in spite of the lack of planting material. First, the banana plantlets generated by rapid multiplication are more expensive than conventional suckers. Also, investing in larger quantities of planting material creates an additional transportation cost, as most multiplication facilities are some distance from the destination field. So the investment is greater than the price per plant. Second, price volatility may deter farmers from increased investment in plantains. During the glut season, prices per bunch may be too low for farmers to make a profit, and they may even lose money. During the lean season, prices are much more interesting. Initiatives are currently underway to examine irrigation so farmers can access these higher prices.

The multiplication technology continues to be used by government organizations as a rapid and cost-effective method to produce large quantities of planting material.

3.2 AFFORDABILITY OF THE NEW HYBRIDS AND CLEAN PLANTING MATERIALS

Training, materials for building the nurseries, and the TC plantlets of the new hybrids were supplied to farmers during the project free of charge. The new hybrids aimed to increase farm productivity, leading to improved food security and opportunities to earn cash. Major constraints for further adoption of new banana and plantain technologies were related to uncertainties from insecure land tenure (for those who do not own their own farms) and access to credit (Dzomeku et al. 2010a). The hybrids' taste and texture were too similar to banana, when cooked for too long, making the boiled pulp soggy. This made the hybrids less acceptable in the market. The shelf-life of the fruits also discouraged the adoption of the hybrids, and at least one hybrid had production deficiencies related to banana streak virus (BSV).



A farmer with her humidity chamber for multiplying banana plantlets. Such an innovation requires investment and new skills. Photo by Beloved Mensah Dzomeku.

However, resistance to black Sigatoka is a plus for their use as a shade crop for young cocoa seedlings.

3.3 SEED QUALITY

Seed quality is defined by three main characteristics: health (an absence or tolerable presence of pests and diseases), physiology (vigorous), and genetic (variety).

3.3.1 *Before the intervention*

The project started from the premise that farmers traditionally use suckers from their own plantation, with minimal awareness of pests and diseases spread through infected planting materials. Furthermore, farmers did not always consider the importance of sucker physiology, sometimes planting very tall suckers, for example, which develop weak pseudostems with smaller bunches. Finally, all the popular varieties in Ghana are susceptible to pests and diseases, notably black Sigatoka, nematodes, and weevils.

The TARGET project therefore proposed the transfer of technologies to address these three aspects of quality through training in sucker sanitation technologies (paring and multiplication of clean planting materials, see sections 3.1 and 6), proper sucker selection practices, and dissemination of the resistant hybrids FHIA-21, CRPB-39, FHIA-25, and BITA-3. CRI trained the extension staff, and IITA provided technical backstopping. Farmers were trained by extension staff who carried out field visits.

3.3.2 *What changed as a result of the intervention*

Farmers appreciated the individual visits by extension staff as this reinforced the farmers' sense of belonging to the project, and the meeting was an opportunity to discuss individual needs. After training, which included information on banana production, many of the farms were weed free, mulched, and producing excellent bunches. Farmers were also more aware of proper sucker preparation methods. Indeed, sucker paring was used by almost all participants and half of the nonparticipating farmers interviewed by Dankyi et al. (2007) in the project area. The diffusion of the paring practice reached its peak in 2005, just 2 years after the project started in 2003. Some farmers cited a lack of technical assistance, however, and extension staff made more visits to individual farmers than originally expected. Consequently, transport costs increased. Project staff suggested that future projects increase the emphasis on demonstration plots and printed material (with many illustrations), instead of focusing on many individual visits.

The attitude of smallholders toward the new hybrids was evaluated during a survey of participating communities in the project area (Dzomeku et al. 2010a, 2010b). Initially, farmers were apathetic to the small, TC plantlets, which looked especially fragile in their plastic bags, especially when compared with the sturdy, bulky conventional suckers. Farmers reluctantly agreed to plant the new varieties. After 3 months, farmers observed the superiority of the new hybrids and urged the project implementers to allow them to replant the resulting suckers on their own farms, instead of returning suckers to the project. Farmers were enthusiastic about the yield, vigorous growth, and evergreen leaves of the hybrids (ibid.). Leaves provide shade for intercropped cocoa and could also be used to process cocoa beans (covering the heaps of beans with banana leaves to let the cocoa ferment). One notable

disadvantage of FHIA-21 was that the peel was rather thin, increasing risk of mechanical damage. However, overall FHIA-21 was the variety that farmers preferred among the four they tested because of its taste and commercial potential.

Another indication of the popularity of the hybrids was the complaint of theft, with plants being stolen from demonstration plots in some sites. Communities were made aware that all farmers were going to benefit from the TARGET project because of its built-in mechanism whereby selected farmers had to provide planting materials to non-project farmers.

Despite the general appreciation of the hybrids, farmers remarked that CRBP-39 was highly diseased; many plants gave small bunches, with short fingers, although the food quality was good. Indeed, several instances of BSV were reported on the CRBP-39 hybrid. BSV is a pararetrovirus that can cause severe damage, yet rarely causes epidemics (Lassoudière 1974; Iskra-Caruana et al. 2010). There are two infectious forms of BSV. The first is transmitted via mealy bugs (Daniells et al. 1995), and the other form is derived from a viral sequence that is integrated within the banana B genome (the genome derived from *Musa balbisiana*). Physical stress (cold, drought, heat, TC propagation) can activate such integrated sequences, starting the formation of infectious viral particles. *Musa* hybrids propagated through TC, particularly tetraploids such as CRBP-39, are susceptible to such outbreaks of BSV (Côté et al. 2010). It is not clear from the project documentation at what part in the production pipeline the BSV arose. The exact extent of these events and number of farmers, fields, and villages affected by BSV on CRBP-39 is not reported. B.M. Dzomeku (pers. comm. 2016) reports that FHIA-01 (a dessert banana, not included in the TARGET project) is currently sold at various market sites and is also processed into fruit juice. FHIA-25 (cooking banana) is also common and pervasive in farming systems. FHIA-21 is less available than originally expected, with few mats observed. These varieties were tolerant of BSV and so were more readily adopted in Ghana.

4. Seed producers and seed availability

4.1 THE MODEL

Virus-tested TCs of the selected hybrids were provided by Bioversity International (International Transit Center) to Du Roi Laboratories in South Africa, where this stock material was multiplied using micro-propagation techniques. A target of 16,000 plantlets was allocated to each country of the TARGET project, including Ghana. Plantlets were sent from South Africa to Ghana, but the courier service failed to deliver the package on time. Some plant loss was due to fungal infections incurred during the overdue stay in the courier's office in Kumasi.

It was not possible to wean the plantlets in Assin Juaso as originally planned, because staff at this CRI-outstation was unaccustomed to handling TC plantlets. Therefore, the project opted to wean plantlets at CRI's facilities in Kumasi, and send the weaned plantlets to Assin Juaso just before dissemination to farmers, where the little banana plants could be hardened in a hardening shed. Thus, Assin Juaso functioned as a local transit point until farmers were ready to receive the ready-to-plant hybrids. Some damage occurred to the plants during transportation to farmers in the 10 project communities, but most plants arrived safely.

Although the project decided to give each farmer four varieties to widen their adoption choice, some farmers with less land received fewer varieties; 16,282 hybrid plants were disseminated to 887 participants during the 2 years of the TARGET project (Table 5.1).

Scaling up

Farmers were expected to plant the TC plantlets, and once these were established, to donate suckers back to the project to share with other farmers. Although plant growth was vigorous and leaves were abundant, some difficulties were encountered, including poor sucker production and difficulty identifying the varieties, apparently due to poor labeling by Du Roi. In one of the most sincere signs of farmer acceptance of the new hybrids, some of the farmers were reluctant to release suckers back to the project, preferring to keep the material to plant on their own farms.

The continued distribution of planting materials within Ghana was from farmer to farmer. Social networking played an important role in distributing the hybrids and the technologies, as farmers, extension officers involved in TARGET, and the district director of MoFA all continued to share the innovations after the end of the project.

4.2 BENEFITS FOR THE FARMERS

Advantages of the seed

The farmers liked the taste of the hybrids, which also outperformed the landraces. The resistance to Sigatoka allowed dense foliage, providing shade for intercropped cocoa. High commercial value was anticipated but did not materialize.

Disadvantages of the seed

Timing was a problem, with some delays in the production of the TC plantlets. This resulted in some farmers becoming discouraged and planting other crops in the fields reserved for the hybrids. Planting should coincide with the start of the rainy season, as the TC plantlets are especially susceptible to drought. Few farmers have access to irrigation. The infection of CRBP-39 by BSV was a considerable disadvantage, considering the need to win confidence with the farmers for these new hybrids. More careful inspection before dissemination to farmers might have avoided this problem, although local plant stress factors may also have been a factor in starting the local viral outbreaks.

4.3 QUALITY ASSURANCE AND REGULATION

Quality assurance mechanisms

ITC, established in 1984, provided virus-indexed plantlets to Du Roi Laboratories. ITC functions as a third-country quarantine and is the world's largest in-vitro collection of Musa spp. ITC is managed by Bioversity International and is hosted by Catholic University in Leuven, Belgium.

Du Roi Laboratories in South Africa has an international reputation of providing high-quality banana planting materials. The company was established in 1994 and specializes in producing and distributing disease-free, virus-indexed TC banana plants.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

There are seed regulations and general policies in place in Ghana; however, they are ill equipped to deal with particularities of vegetatively propagated crops. The seed system for grains and legumes is well regulated. The release of crop varieties in Ghana is done via a systematic procedure developed by the National Varietal Release Committee (housed at the CRI), which is chaired by the MoFA. After a new variety is released, breeder seed is supplied to the Grains and Legumes Board for production of foundation seed and sale to certified seed producers. However, the board is not able to produce foundation seed for vegetatively propagated plants. The seed inspection services are unable to index for viruses because they lack the proper training, equipment, and funding.

Seed-related policies

The seed law was passed in Ghana in 2014, almost 10 years after the implementation of the TARGET project. It allows any private person or entity to produce seed without going through the Grains and Development Board. However, the law does require registration with MoFA. Any entity can bring in seed for sale after approval has been given.

5.2 SEED HEALTH AND QUALITY

The appropriate authorities ensure that healthy seed is produced and sold on the market. But as mentioned above, for vegetatively propagated crops this remains challenging due to lack of training, equipment, and funds.

Seed health and quarantine

The Plant Protection Regulatory Seed Directorate of MoFA is responsible for the health and quarantine of any seed import and production in Ghana. The TC plantlets were imported from Du Roi Laboratories in South Africa using a courier service.

6. Seed multiplication tools and techniques

The underground banana stem (rhizome) has several axillary buds at the base of the leaf sheaths. These buds can potentially produce a large number of plantlets. A number of robust, low-cost multiplication methods for Musa planting materials are available, including false decapitation, complete decapitation, excised corm (microcorms), split corm, and a macropropagation technique via bud manipulation. These techniques are easy, affordable alternatives for TC, thus providing a means for large-scale sucker production at the farm level. These methods can generate 16–50 or more plantlets from one sword-sucker corm using sawdust as plantlet initiation medium. Farmers were already using (false) decapitation techniques and the split-corm technique, although the extent to which these technologies were adopted is unknown. The technologies are summarized below:

- False decapitation relies on destroying the actively growing region (meristem) of the mother plant, which stimulates the growth of new plantlets from the axillary buds. When the suckers reach a height of 30–40 cm, they are detached and planted directly in the field.

- In the excised corm technique (microcorms), the large visible buds and some of the surrounding corm tissue are carefully removed and replanted in polyethylene bags and regularly watered, to keep the soil moist.
- In the split-corm technique, the corm is split into two or more fragments that are planted in soil with the axillary buds facing down. Sprouted plantlets are detached and potted before transplanting to the field.
- Macro-propagation is the most complex multiplication method. A medium-sized corm with a diameter of approximately 10 cm is obtained from a healthy mat. The sucker is pared (removal of roots and outer cortex of the corm). The pseudostem is then cut 20 cm above the collar, leaf sheaths are removed individually to expose axillary buds, and the apical meristem is removed. The corm is placed in sawdust or another medium in a humidity chamber, where axillary buds develop after 3 weeks. This technique can produce up to 30 plantlets in 10–18 weeks. The plantlets are detached, rooted in soil in a low-light chamber, and then hardened under direct sunlight.

7. Lessons

At the start of the intervention, project designers lacked information of existing seed systems and quality.

Planting season must be considered for any banana project since the crop is usually planted with the first rains. The plants should be weaned, hardened, and ready to plant at the onset of the rainy season. The late arrival of the planting material in Ghana did not coincide with the planting season. Farmers were unable to wait any longer and planted other crops instead of banana.

Some hybrids were infected with BSV. The planting material provided to farmers should be disease free to gain the farmers' trust in the intervention.

Give farmers more written information on banana production so that they can find answers to their problems easily. Some farmers did not remember all the issues that were taught in the training sessions.

Farmer networks and organizations are a viable dissemination route, and should receive similar or more attention than dissemination via extension and research organizations.

References cited

- Cote FX, Galzi S, Folliot M, Lamagnere Y, Teycheney PY, Iskra-Caruana ML. 2010. Micropropagation by tissue culture triggers differential expression of infectious endogenous banana streak virus sequences (eBSV) present in the B genome of natural and synthetic interspecific banana plantains. *Molecular Plant Pathology* 11:137–144.
- Daniells J, Thomas JE, Smith M. 1995. Seed transmission of banana streak virus confirmed. *Infomusa* 4:7.

- Dankyi AA, Dzomeku BM, Anno-Nyako FO, Adu-Appiah A, Antwi G. 2007. Plantain production practices in the Ashanti, Brong-Ahafo and eastern regions of Ghana. *Asian Journal Agricultural Research* 1:1–9.
- Doss CR. 2002. Men’s crops? Women’s crops? The gender patterns of cropping in Ghana. *World Development* 30:1987–2000.
- Dzomeku BM, Armo-Annor F, Adjei-Gyan K, Ansah J, Nkakwa A, Darkey SK. 2008. On-Farm Evaluation and Consumer Acceptability Study of Selected Tetraploid Musa Hybrids in Ghana. *Journal of Plant Science* 3:216–233.
- Dzomeku BM, Staver C, Aflakpui GKS, Sanogo D, Garming H, Ankomah AA, Darkey SK. 2010a. Evaluation of the dissemination of new banana (*Musa* spp.) technologies in Central Ghana: The role of technology characteristics. *Acta Horticulturae* 879:735–740.
- Dzomeku BM, Armo-Annor F., Adjei-Gyan K. 2010b. Smallholder farmers’ attitude towards biotechnologically developed Musa hybrids in Ghana. *Aspects of Applied Biology* 96:225–231.
- Dzomeku BM, Dankyi AA, Darkey SK. 2011. Socioeconomic importance of plantain cultivation in Ghana. *The Journal of Animal and Plant Sciences* 21:269–273.
- Dzomeku BM, Asigri M. 2012 Consumer preference for two FHIA hybrids (FHIA-01 and FHIA-25) and Cavendish bananas in Ghana. *Annals of Food Science and Technology* 13:279–283.
- Iskra-Caruana ML, Baurens FC, Gayral P, Chabannes M. 2010. A four-partner plant-virus interaction: Enemies can also come from within. *Molecular Plant-Microbe Interactions* 23:1394–1402.
- Lassoudière A. 1974. La mosaïque dite “à tirets” du bananier Poyo en Côte d’Ivoire. *Fruits* 29:349–357.
- Lescot T. 2012. The genetic diversity of banana. *Close-up FruiTrop*, No. 200.
- Schill PF, Afreh-Nuamah K, Gold CS, Green KR. 2000. Farmers' perceptions of constraints to plantain production in Ghana. *The International Journal of Sustainable Development & World Ecology* 7:12–24.
- Staver C, Lescot T. 2015. Propagating quality planting material to improve plant health and crop performance, key practices for dessert banana, plantain and cooking banana: Illustrated guide. Montpellier, France: Bioversity International.
- TARGET (Draft Final Report). 2007. Increasing productivity and market opportunities for banana and plantain. A strategy for economic growth for rural communities in Africa. A concept note developed jointly by the International Plant Genetic Resources Institute (IPGRI) and IITA. 96p.
- [UNDP] United Nations Development Programme. 2013. Ghana country report. (Available from <http://www.undp-gha.org/design/countryinfo/>) (Accessed on 9 October 2013)

CHAPTER 6

Clean vines for smallholder farmers in Tanzania

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Abstract

Marando Bora (“Better Vines”) was a project designed to share healthy sweetpotato vines (for planting) with 150,000 farmers in Tanzania. The project trained some farmers to produce sweetpotato vines alone and others as groups. Women farmers often appreciated producing vines in groups as a way of overcoming the scarcity of land and other resources. These vine producers would sell their material to other farmers, who would pay with subsidized vouchers. The vine growers produced several improved varieties, which they reproduced from virus-free material, to help farmers acquire higher yielding plants, although in practice the material was rapidly re-infected in the field. The project was implemented by various NGOs. There were problems with an early attempt to piggyback vine production onto existing cassava seed groups. Cassava is grown by men, and sweetpotato by women. Cassava can thrive on dryer land than sweetpotato. Training and facilitating FGs is time-consuming, and some of the NGOs could not keep up with all of their groups. In the second year of the project, more vines were produced en masse at central points. Some vines were given to farmers for free at schools, reducing the transaction costs of the voucher system. The project sensitized farmers to buy the vines, although this was of no use if the vines were not ready on time. Virus-free seed can improve yields, if farmers buy enough vines to plant a whole field.

Rationale

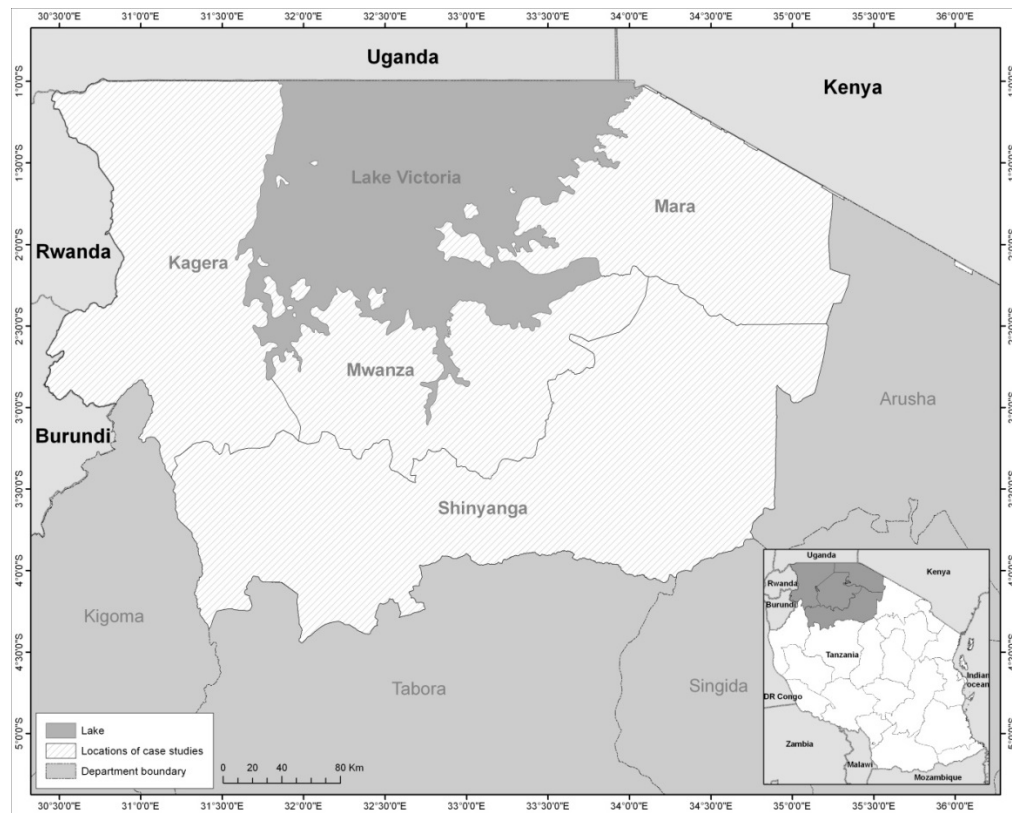
In East Africa, sweetpotato is an important food security crop, which is widely managed by women to feed their families. The perception of sweetpotato as a woman’s crop, grown by poor people, has meant that until recently it has not received the research and attention it deserves. Sweetpotato is often planted from vines of the mature plant and is susceptible to pests and diseases, leading to degeneration. These vines are most conveniently gathered at planting time, which means that the vines are often unavailable when farmers need to plant them.

1. The intervention

The Sweetpotato Action for Security and Health in Africa (SASHA) Marando Bora (“better vines” in Swahili) project tackled critical problems of sweetpotato production with a seed system intervention to improve the quantity and quality of food in 150,000 Tanzanian HH (CIP and BMGF 2009). The project aimed to address three challenges:

- The need for farmers to get timely access to vines in the planting season; the vines are often difficult to keep through the dry season.
- The need for virus-free, high-yielding vines.
- Enhancing the success of breeding programs by more efficiently multiplying and distributing seed to farmers.

Previous sweetpotato seed interventions in SSA had tried mass multiplication and dissemination (Potts 2006), but these were often wasteful and offered farmers little choice of variety or planting time. Based on experiences in Mozambique (Low and Arimond 2007), there was interest in testing a large, decentralized vine multiplication approach, and in using subsidized vouchers to promote farmer demand for sweetpotato seed.



The theory of change

Decentralized vine multipliers (DVMs) would be chosen and trained to produce quality planting material to be available at the start of the rains. Farmers would learn of the benefits of these vines, with demand stimulated by subsidized vouchers for women and for HH with children under 5 years. Farmers would plant improved varieties and obtain higher yields, leading to improved HH food and income security, leaving DVMs with regular seed customers.

Project activities included:

- a) Providing high-yielding vines of robust varieties preferred by farmers and orange-fleshed sweetpotato (OFSP) varieties to help reduce vitamin A deficiency in the Lake Zone (around Lake Victoria).
- b) Ensuring that virus-free vines were delivered early in the growing season.
- c) Training farmers to conserve vines over the dry season.
- d) Training vine multipliers to become permanent sources of quality planting material.

The component was led by CRS, a sub-grantee to CIP, in partnership with implementing partners (IPs) which included the following local NGOs: Buhemba Rural Agricultural Center (BRAC), Catholic Diocese of Shinyanga (DoS), Kituo cha Mafunzo ya Kuboresha Mazingira na Kilimo Adilifu (KIMKUMAKA), Mogabiri Farm Extension Centre (MFEC), Mwanza Rural Housing Project (MRHP), Rulenge Diocesan Development Office (RUDDO), and Tanzania Home Economics Association (TAHEA). The NGOs, in collaboration with local government agricultural extension agents, coordinated conservation and multiplication of vines. The IPs trained farmers or groups to multiply the vines. Mikochei Agricultural Research Institute (MARI) in Dar es Salam and Helen Keller International (HKI) were separate sub-grantees with CIP. HKI implemented a communication strategy on “quality vines for increased harvests” and “orange-fleshed sweetpotato for good health.” The organization also provided signboards for the vine multipliers and ran radio jingles and several “market storms” to promote the vines.

Several changes to the design were made at the start of the project and during its life:

- a) At the start, the idea was to piggy-back the sweetpotato seed intervention onto the existing Great Lakes Cassava Initiative (GLCI) seed system. However, sweetpotato seed production is more difficult than cassava seed production. Sweetpotato is mainly grown by women (often in small plots near the home), whereas cassava is often considered a man’s crop, grown in open fields. Many of the GLCI multipliers were men who were unfamiliar with sweetpotato.
- b) CRS had much experience with the voucher system, having previously implemented the C3P which piloted vouchers in the Kagera Region. However, in the Mwanza and Mara regions where Marando Bora started, there was no voucher system for cassava; the sweetpotato voucher system was thus started from scratch.
- c) Initially, it was assumed that each NGO would be able to handle more than 50 vine multipliers. However, the first distribution season (January–March 2011) showed that the multipliers needed more supervision and each partner could only support 20–30 of them. This reduced number of

DVMs meant that this model would not be able to reach the targeted 150,000 HH. A second model was proposed: mass multiplication and dissemination. Planting materials were multiplied on a large scale in central locations and then distributed to farmers.

The project ran from October 2009 to June 2012 (less than 3 years), and reached an estimated 112,000 farmers in 16 districts in four regions of the Lake Zone with 88 DVMs. Some 10 million cuttings of five improved varieties ('Ejumula', 'Ukerewe', 'Polista', 'Kabode', and 'Jewel') were produced. In October–November 2011, in areas where DVMs had achieved maximum coverage, planting material was also disseminated through 42 schools, reaching 11,822 HH (included in the 112,000). Of the DVMs 67.5% were women (mostly working in groups) and 74% of the vine recipients were women. Many farmers obtained improved sweetpotato planting material through the project. When the project was designed, planting materials were in short supply at the start of the rains, mainly because farmers did not know how to conserve vines. By the end of the project there had been some change. The endline survey (Okello et al. 2013) showed that most HH were now willing to conserve vines.

Present status. The project has ended, but several other projects are continuing its themes and making use of some of the lessons learned about sweetpotato seed production and distribution. There were independent, individual producers and distributors of sweetpotato vines operating in the area before the project. They continue to work now, as private businesses, often on a small scale.

Framework: Sweetpotato in Tanzania

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Policy-makers	Project attended district council meetings			Explained importance of sweetpotato, esp. OFSP to local leaders		TOSCI is considering standards for certified & QDS sweetpotato seed
National research		Kenya was source of clean seed				Produced in-vitro seed
International research	CIP led the project, to make seed available to farmers at low cost	Project organized FGs (DVMs) & vine growers, mostly near farmers	Project subsidized the cost of the seed	Shared info of OFSP products, & of DVMs with posters, radio, t-shirts, caps & market storms	Provided & promoted OFSP	Re-infection by virus a constant problem
Traders (local markets)	Project specifically ignored them					
Private seed sector		Some private growers produced seed				Reared clean seed
Farmer organizations	Project organized DVMs					Used net tunnels
NGOs	CRS & local NGOs* were CIP sub-grantees	The NGOs organized DVMs & distributed seed		Conducted awareness campaigns (see above)		Trained seed growers to manage pests & diseases
Private sector processors		Not key in this effort				
Seed users		Users often lived in same village as DVMs	Vines were low-cost, or free	Project targeted women to use the seed		

*NGOs: BRAC; DoS; KIMKUMAKA; MFEC; MRHP; RUDDO; and TAHEA.

2. General context

Sweetpotato (*Ipomoea batatas*) is the third most important root and tuber crop in Tanzania after cassava and potato (*Solanum tuberosum*) (Adam 2014). Sweetpotato production in Tanzania more than doubled, from 1,396,400 t in 2006 to 3,100,000 t in 2013 (FAOSTAT 2014).

The crop is particularly important in the six regions making up the Lake Zone with 15 million people, a third of Tanzania's population. In the Lake Zone, sweetpotato complements other crops and is a food security reserve when cereals fail. The crop has a short growing season, so it can take advantage of limited rainfall. Sweetpotato is planted alone or mixed with cassava, cowpeas, maize, beans, bananas, or fruit trees. Farmers who have moist, low-lying land often grow a dry season crop. Farmers prefer varieties that are high yielding, drought tolerant, and "not watery" (Sindi and Wambugu 2012). Most farmers grow the white- and yellow-fleshed varieties to eat at home, usually boiled but also deep fried and eaten as a snack, especially in cities. Only 35% of farmers grow sweetpotato for sale.

OFSP varieties were first introduced into the Lake Zone in the early 2000s. Farmers rejected the first generation of varieties, which were watery, perishable, and susceptible to drought and diseases. Most farmers exposed to these varieties were close to research stations or supported by NGOs (Jeremiah and Kulembeka 2007). The OFSP varieties are relatively scarce in local markets, and farmers growing them tend to eat them at home and sell the white ones to the Mwanza urban market (Mafuru and Kibura 2009; Mafuru 2009).

Constraints to sweetpotato production include limited supply of quality planting material of improved varieties. Viruses accumulate in recycled planting material and lower yields by 56–98% (Mukasa et al. 2003). Sweetpotato weevils (*Cylas* spp. and *Blocyrus* spp.) are the main insect pests. Long dry periods and low soil fertility also limit yields (Kapinga 1995). Government extension services have paid little attention to the sweetpotato as it is considered a woman's or a poor person's crop and not a cash crop.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

Farmers said that there was insufficient planting material at the start of the rains because of the difficulty of keeping vines over the dry season. Breeding programs were developing higher-yielding, drought-tolerant, virus-resistant, and vitamin A-rich sweetpotato varieties with moderate to high dry matter content. But the programs were only sharing new varieties with farmers who lived close to research stations or were involved in on-farm trials.

About 42% of the baseline survey respondents mentioned ‘Polista’ as their favorite variety, followed by ‘Kilihona’ (7.5%) and ‘Ushashini’ (4.7%) (Sindi and Wambugu 2012). ‘Jewel’ and ‘Ejumula’, OFSP varieties introduced under previous interventions, were being grown by a mere 3.2% and 1% of farmers; 16% of the baseline respondents had dropped ‘Simama’ and ‘Mwezigumo’, varieties previously introduced by the national agricultural research institutes (NARIs), due to low yields.

Small quantities of planting material are conserved during the dry season and used to plant during the short-rain (November/December) to obtain vines (and some roots) for the main season for the root crop in February/March (Namanda and Gibson 2011). Farmers may also deliberately leave a portion of the field unharvested, or take advantage of roots missed during the harvest, which sprout at the next rains. Those who do not have moist, low-lying land acquire cuttings from their neighbors (Sindi and Kiria 2011). Women cultivate sweetpotatoes, and conserve the vines, depending on the amount and type of land they have, their age, training in sweetpotato production, and value of the crop (Adam 2014). Men and children help with tasks such as land preparation, ridging, and weeding.

The baseline study in August 2010 showed that 63% of the survey respondents conserved vines during the long, dry period and about a quarter of them (25.9 %) got their vines from other farmers in the village, especially from female neighbors (Sindi and Wambugu 2012). Some 56.3% of the respondents said they leave part of the crop unharvested and wait for the rains, 29.6% conserve in wetlands, and 25.4% keep their vines under the shade of other crops (Sindi and Wambugu 2012). The third source of vines were vine multipliers located relatively far from the farmers’ fields (9.8%) (Adam 2014). Some farmers sourced vines from the lakeshore (5.3%), and only a few on better roads were able to get vines from NGOs (0.3%).

Farmers in the project areas mainly grew white- or cream- fleshed sweetpotatoes, and often mixed different varieties together. This was done partly because of the limited supply of planting materials, as a way of spreading risk, and for harvesting at different times.



Harvesting vines is a chance for groups to work together—here, Ryamweze DVM group Musoma. Photo by M. McEwan.

3.1.2 What changed as a result of the intervention

To start with “clean” (i.e., disease-free) material, in 2010 the project introduced a seed system with virus-indexed TC plantlets: 36,473 plantlets were supplied through the Kenya Plant Health Inspectorate Service (KEPHIS) and from GTIL, a private TC laboratory in Nairobi. Hardening was conducted at the Maruku Agricultural Research and Development Institute (MARDI), Bukoba (an area with low virus pressure), and a pre-basic (foundation) vine multiplication site was established. From there, the materials were transferred directly to DVMs in Mwanza and Mara regions, or to one primary multiplication site (PMS) or two secondary multiplication sites (SMS) managed by researchers and NGOs. In 2011, the PMS and SMS supplied additional DVMs as they were established in other regions. In late 2011, seven of the most successful DVMs became medium-scale multipliers to contribute to the supply of vines for the mass dissemination model.

Decentralized vine multiplication ensured that the bulky and perishable sweetpotato planting materials could be accessed by farmers at the community level. DVMs were within walking distance, so farmers could collect the vines when they were ready for harvesting and the farmers prepared to plant. Farmer beneficiaries could go back to the DVMs if their materials were lost during a dry spell. The 88 DVMs helped to supply 83,829 farmers with about 10,059,480 cuttings.

Each DVM received Tsh. 2,541,279 (\$1,588) in input and voucher subsidies (Lembris and Walsh 2012). Participation in the project increased farmers’ likelihood of planting clean materials and OFSP varieties, one season after the intervention had finished (Okello and Sindi 2014).

Three orange-fleshed and two cream-fleshed varieties were disseminated; but there was not enough time at the start of the project to validate these varieties. Although some varieties had been nationally released, they had not been validated in the Lake Zone. Other varieties were in the release pipeline, or had been released in Uganda but needed wider testing and evaluation. Varieties should be validated through farmer participatory trials before large-scale multiplication and dissemination.

By the end of the project, farmers preferred the white-fleshed local ‘Polista’, followed by the project’s ‘New Polista’, which farmers usually called ‘Marando Bora Polista’ (Okello and Sindi 2014), and which had been cleaned of viruses. The OFSP ‘Kabode’ variety ranked third. Initially (2010–2011), farmers asked, “Why should we be given ‘New Polista’ when we have ‘Polista’”? However, after farmers saw the improved yields that their neighbors were getting with the cleaned-up ‘New Polista’, they were convinced there was a difference. Unfortunately, the demos (comparing clean and farmer-selected ‘Polista’) were not implemented in the first season and were not harvested in the second season. By the third season, some demos were planted, and the project staff did a crop cut in August 2012, which showed a difference. In interviews with the authors, farmers consistently said that the ‘Marando Bora Polista’ sprouted more quickly than their own ‘Polista’, yielded more, and tasted sweeter. (It may have had less weevil damage.)

A stakeholder meeting held two years after the end of the project showed that ‘New Polista’ and ‘Kabode’ were still preferred because they tolerated drought and disease. There is little demand for the varieties ‘Jewel’, ‘Ejumula’, and ‘Ukerewe’ because they are susceptible to diseases and have low dry matter.

3.2 AFFORDABILITY OF THE SWEETPOTATO VINES

The project's subsidized voucher system ensured that female farmers and HH with children under 5 years could access the improved planting material. With the vouchers, farmers could choose which varieties they wanted and collect and plant the vines when there had been enough rain.

The voucher beneficiary (farmer) paid US \$0.07 to the multiplier (for a bundle of 100 cuttings); the project paid \$0.33 when the voucher was redeemed. Very few farmers were unable or unwilling to pay the \$0.07.

It cost the DVMs \$0.30–40 to produce 100 cuttings (including the value of the subsidies they received, but not their labor or land), which is more than the vine multipliers were receiving. In November 2012, (after the project) some DVMs in areas with high demand for vines had increased the sales price to \$0.43 for 100 cuttings.

Data for the potential yield and income benefit from using cleaned-up material were collected from demo plots and a crop-cut exercise for the 2011/12 season, which had poor distribution of rainfall. Yields and income were higher for varieties disseminated by the project.

Pricing and affordability of vines. The subsidized cuttings were affordable, although many multipliers felt that the price did not reflect their costs. The vouchers stimulated some cash sales of vines, but this led to distortion of the existing market during the life of the project. The token payment by voucher recipients was expected to increase ownership and willingness to pay for clean vines. However, there were very few unsubsidized cash sales, possibly because (1) the project met the demand for seed through the vouchers, (2) farmers who did not get vouchers did not know about the clean vines for sale, or (3) farmers were not willing to pay for vines. This questions the sustainability of the initiative. However, 69% of DVMs were still multiplying for sale, or for own use nine months after the project finished, compared with just 18% who were multiplying when the project started.

Follow-up surveys with the DVMs nine months after the intervention indicated that many people will only buy vines to obtain new varieties. Farmers are most likely to buy just small quantities of new varieties to test—it may be unrealistic to ask them to buy 100 vines of an unfamiliar variety. In some areas close to well-developed markets for roots, farmers will buy planting material. People will also travel up to 60 km to buy vines if they cannot conserve them over the dry season in their area.

3.3 SEED QUALITY

3.3.1 Before the intervention

Before the project, women farmers used their own experience and knowledge to select and conserve vines. However, the use of recycled planting materials in the Lake Zone has lowered sweetpotato yields. The baseline survey showed that only 2% of the respondents could correctly attribute disease symptoms to viruses. Most of the farmers did not rotate crops, contributing to the high losses from weevils and viruses.

3.3.2 What changed as a result of the intervention

The staff of the IPs were trained to identify and manage pests and diseases. This information was shared with the DVMs through training and monitoring and supervision. Some DVMs passed on this knowledge to the farmers who came to get planting material, and through field days at demonstration plots. Some DVMs and farmers changed practices (e.g., rouging, site selection, using seed beds, and conserving seed) (Okello et al. 2013). The intervention area was a virus hot-spot, and some of the more susceptible varieties ('Ejumula', 'Jewel', and 'Ukerewe') were quickly and severely affected by virus diseases. IPs, DVMs, and farmers did become more aware of sweetpotato viruses. Researchers and development practitioners placed more value on decentralized quality management.

The project taught the importance of clean planting material through educational campaigns and signboards. The project helped to build inexpensive net tunnels to protect pre-basic (foundation) planting material at the two research stations. There were problems with construction and maintenance, however, so the tunnels did little to maintain quality. Sweetpotato virus diseases hindered the project. Some varieties were already diseased at primary multiplication sites and worsened at secondary and tertiary sites. The 'Ejumula', 'Jewel', and 'Ukerewe' varieties were especially susceptible to viruses. The sweetpotato diseases diminished the project's success and prevented a sustainable sweetpotato seed system from being established.

Seed system practitioners should use several strategies to manage sweetpotato viruses. The net tunnels may help to protect planting material. Multipliers and farmers must be trained to identify and manage diseases. The training should be monitored if a training of trainers (ToT) approach is used. Farmers' real demand for clean seed must be clearly understood.

4. Seed producers and seed availability

4.1 THE MODEL

Two models for disseminating planting material were tested. The first model used vine multipliers to supply farmers at the village level in exchange for vouchers. The second model used mass multiplication and dissemination from central distribution points.

4.1.1 Model 1: vine multiplication at village level

Implementing partners trained farmers (or groups) to produce vines to exchange for vouchers within a radius of 10–12 km. The DVMs were trained in rapid multiplication, disease and pest identification and management, and how to use the vouchers. Some 28% of the DVMs operated as individual farmers (28% female, 72% male) and 72% worked as FGs (with up to 20 members), of which 68% had 50% or more female membership. The DVMs were selected based on their interest and experience with sweetpotato and vine multiplication, access to a year-round water source, a good site for growing vines, trustworthiness, and good community standing. Some DVMs received fertilizer and small-scale irrigation equipment. Some (21%) of the DVMs were from GLCI-supported FGs, 8% were from Savings and Internal Lending Communities (SILC) groups, and the remaining 62% were new.

The voucher system was designed so that beneficiaries would be identified, receive vouchers in advance, and know where they could exchange the voucher for vines. Farmers could receive the vines when they were ready to plant and choose the varieties they wanted; and the DVMs could be a nearby

source of information for farmers. The vouchers gave the DVMs a guaranteed market. Three IPs (BRAC, KIMKUMAKA, and TAHEA) were contracted to train and supervise the DVMs in eight districts (Musoma Rural, Bunda, Magu, Misungwi, Mwanza, Geita, Ukerewe, and Sengerema).

The vouchers were piloted in the December 2010–March 2011 season, and revised (with self-carbon forms) after DVMs and IPs noted the long time needed to complete all the forms. The vouchers successfully targeted women, who redeemed 76% of the vouchers; 75% of voucher recipients had a child under 5 years. Women preferred the OFSP varieties. The voucher redemption rate was high (90%), possibly reflecting the use of schools and the “on-the-spot,” same-day issuing and exchange of vouchers (37% of vouchers were exchanged on the day they were issued). The vouchers did not fully achieve their objective of allowing the farmers to collect their planting material at flexible times. The cost of implementing the voucher system was greater than the value of planting material.

Piggy-backing sweetpotato seed onto cassava. The project design assumed that the sweetpotato seed system would build on the GLCI cassava seed system. But this only worked in a few cases because the two crops have different requirements. For example, sweetpotato needs water to produce vines during the dry season, whereas cassava does not (CRS 2012a). The partner supervisors were expected to take on additional responsibilities, through recruiting additional junior staff and contact farmers. Transport (motorbike or bicycle) and training events were expected to be shared or co-organized. Sweetpotato seed dissemination was a burden on the IPs, and additional funds were allocated to provide more staff time and overhead (CRS 2012b). However, there were some savings on management, and synergies at other stages could be more successful (e.g., shared diagnostic and in-vitro multiplication and hardening facilities).



Quality starts at source: TC sweetpotato plantlets.
Photo by M. McEwan

Gender and vine multipliers. Piggy-backing sweetpotato onto the cassava seed system also ran afoul of the gender division of labor for the two crops: Cassava is generally managed by men, and sweetpotato by women. When cassava multipliers were first asked if they would be interested in multiplying sweetpotato, the response was often “it is better that you talk with my wife.” As a crop becomes more profitable or project-driven, however, men are keen to capture anticipated benefits.

Research suggested that only women should be identified and trained to become DVMs (Benjamin and Badstue 2010; Benjamin et al. 2010). But the selection criteria for DVMs (e.g., literacy and access to suitable land) were barriers to women. After much heated debate at the 2010 annual review and planning meeting, the project set a target that at least 70% of beneficiaries should be female and that most of the DVMs should be female. Project partners began involving more women's groups as DVMs, assuming that as a group, women could better access land and irrigation equipment. The percentage of women involved in the DVM activities rose from 56% (October 2010) to 67% (June 2011). Nine months after the intervention, 72% (63) of DVMs were groups and 940 farmers belonged to them, of which 51% (479) were female.

The business case. Many DVMs, particularly those with land, water, and irrigation, claimed that sweetpotato vines are less profitable to grow than horticultural crops (e.g., tomatoes and cabbage). While multiplying vines, some groups ran out of funds, especially for land preparation and for irrigation during dry spells.

In hindsight, an economic analysis of vine multiplication should have been conducted earlier in the project. During the project, the vouchers gave the DVMs a guaranteed income. Yet there was a concern that few of the DVMs had marketing and enterprise skills, that they would be out of business at the end of the project, and that this would affect their livelihoods. Growing more sweetpotatoes is only useful if there is a stable market for them.

The capacities of IPs. The DMVs did not reach their target of 150,000 HH. Not enough vines could be multiplied due to high disease incidence, long dry periods, and the limited capacities of IPs. The project assumed that these partners could manage 50 DVMs each. But this was ambitious; one partner could only handle 20. ToT courses were given to IPs, including paid field agents and government extension officers. However, little of the knowledge acquired was systematically passed on to farmers; most did not know enough about the varieties and where to get the planting materials. Of the target 150,000 farmers, 85,029 were reached through the DVM model. The project started a mass dissemination model in 2011 (Model 2).

The scaling approach for the project was first calculated on the back of an envelope, without a reality check in terms of the population/catchment of each proposed DVM, and the actual number of DVMs which would be needed to reach 150,000 HH.

The IPs were the same as those that CRS had been using for GLCI, and they thought that the sweetpotato seed production would be no more difficult than cassava. Suitable sites had to have water, however, so it took longer to identify the potential farmers and groups to be trained and supported as DVMs. Piggy-backing sweetpotato onto cassava was supposed to be a cost-sharing measure (e.g., staff, transport, even joint training with cassava). But after the first small dissemination (January–March 2011), it became obvious that this was not going to work. This led to the second model: increasing the budget and bringing in a CIP staff member to provide support.

4.1.2 Model 2: Mass multiplication at central points

After the first dissemination period (March 2011), the project realized that IPs would not reach the target of 150,000 farmers. An additional partner, RUDDO, was contracted to expand the DVM model to

three more districts—Biharamulo, Chato, and Bukombe. Project partners agreed to introduce a second model: mass multiplication at secondary sites, where the seed would be harvested and transported to central distribution points. Three new partners (i.e., DoS, MFEC, and MRHP) were contracted to implement this model in four additional districts—Tarime, Rorya, Kwimba, and Maswa. The IPs used the GLCI and SILC projects and their grassroots structures such as paid field agents and volunteer field agents to coordinate activities such as community sensitization, planning, and vine dissemination. SILC did not have seed multiplication as an activity, but had an extensive network at the community level that could be mobilized for mass distribution. GLCI had experience disseminating cassava planting materials, and SILC had much experience working with communities.

The research design was adjusted to compare the adoption rate of the planting material across the two models. To avoid overlap, planting materials under the mass dissemination model were delivered in separate districts and not where the DVM model was operating. Under this model, planting materials were distributed for free and not exchanged for vouchers.

The DVMs were right in the villages, so that the consumer could see the vines in the field. With mass distribution, farmers were less able to assess performance before planting. Also, there was the risk of high losses of vines during transport and handling over long distances.

An advocacy and communication strategy covering both models was developed with activities targeted at consumers, farmers, multipliers, and decision-makers through posters, radio jingles, t-shirts and caps, and FAQ clinics, as well as district council sensitization sessions as part of quarterly meetings. The project also used “market storms,” where the truck arrives on market day, accompanied by loud music, dancing men, loudspeakers with messages, interactive quizzes, demonstrations of OFSP products, and information on the nearest DVMs.

Signboards were planned to be placed at DVM sites in June and July 2011. However, at that stage the DVMs only existed on paper. This meant that signboards were not delivered for two-thirds of the DVMs until six months before the end of the project. More effective marketing skills were needed for the DVMs.

There was limited benefit to sensitizing farmers about clean planting material unless the vines were available at planting time. Planning was weak, so it was difficult to promote the vines just before they would be available from the mass multiplication sites.

The project never had enough money to train IPs, DVMs, extension workers, and farmer facilitators on nutrition messages about OFSP. The nutrition training for the DVMs was planned to be completed by July 2011; however, it would have been better planned for March and April (after the first root harvest).



Mass dissemination model: Open-sided truck transporting vines for mass dissemination. Photo by M. McEwan.

These funds were then reallocated to cover the communication activities now needed for the mass dissemination model. Because of this, farmers had limited knowledge of the nutritional advantages of sweetpotato.

Advocacy with district-level decision-makers also required good timing. When the meetings were booked, two districts suggested holding the meetings earlier, when the project starts. Organizing separate meetings may be important, but it also costs more. Decision-makers also need some concrete activities to see. One meeting was inadequate for encouraging increased investment in sweetpotato. Decision-makers should be targeted with various advocacy activities (e.g., field visits) at the district and community levels. Communities should also be engaged so that they demand sweetpotato projects.

4.2 BENEFITS FOR THE FARMERS

To be successful and benefit farmers, DVMs need to be able to obtain new varieties from researchers on a regular basis and be able to get fresh material if diseases and pests build up. During this short project, the links between DVMs and research were not institutionalized, undermining the system's sustainability.

Data from demonstration plots and crop cuts on farmers' fields showed the profitability of using clean seed; however, this may mean little under real farming conditions. Even when they understand the importance of clean seed, most farmers only buy a few vines that they can multiply themselves.

4.3 QUALITY ASSURANCE AND REGULATION

Pilot seed inspections were conducted over two seasons in 2012. For the first season, 64% of all plots inspected achieved the "acceptable" standard, based on the locally negotiated tolerance levels; but this fell to 55% of plots in the second season.

The cost of inspecting one site was \$25 using the district plant protection officer but only \$10 when using the village extension officer. As two inspection visits are recommended (2–3 weeks after planting and 2 weeks before harvest), the total inspection cost per site is between \$20 and \$50. It is difficult to develop informal quality assurance systems over multiple, dispersed, small sites, especially if there are few laboratories for testing the source material. On small plots, the cost of inspection with the district plant protection officer is an unrealistic 375% of the value of the planting material. However, costs fall dramatically if plots are 0.5 ha or larger and with a plant population of 250,000 cuttings.

During the pilot, farmers said that the inspections were useful, and helped them to learn more about diseases and pests. DVMs appreciated having a standard against which to judge their own material. Thus using a participatory approach and an emphasis on learning rather than policing is critically important (as was found in the case with potatoes in Ecuador; see Chapter 2).

5. Regulation and policy affecting farmers' use of quality seed

Grain crops in Tanzania have formal inspection and certification schemes. The QDS class is recognized in the legislation, but it was too impractical and costly to use for sweetpotato (McEwan et al. 2013a). The FAO standards for vegetatively propagated crops were published in 2010, and this project tested them as part of a community-based inspection scheme. This was the first time that QDS seed

standards had been tested for sweetpotato in SSA. The project's findings were brought into the dialogue with the Tanzania Official Seed Certification Institute (TOSCI). Under the follow-up project "Kinga Marando," the dialogue has continued and standards have been proposed for pre-basic, basic, and certified sweetpotato seed in addition to QDS. In March 2015, there was a joint meeting for cassava, potato, and sweetpotato with TOSCI. The standards and protocols for the seed classes for all three crops will probably be approved by the MoA by the third quarter of 2015. The Marando Bora project provided the evidence to use more realistic standards, rather than the global ones proposed by FAO.

6. Seed multiplication tools and techniques

Three seed multiplication techniques were used: TC, RMT, and conventional multiplication. TC produces large quantities of disease-free plantlets at pre-basic level. An RMT uses small vines with three nodes, and closely planted (10 x 20 cm) to produce more planting materials within a small area. Rapid multiplication was new to the multipliers, but they adopted it during the dry period (May–October). RMT produces a lot of material on a small piece of land, and the beds are easy to manage. In the project, the standard bed size was 6 x 1.2 m (7.2 m²), but multipliers adapted them, making beds that averaged 5.5 x 0.8 m (4.4 m²). One disadvantage of RMT is the extra cost of irrigation: from TShs. 3,600 (\$2.25) to 4,500 (\$2.80) per bed for 5 months.

Vine multiplication rates and irrigation needs. The project only achieved a multiplication rate of 3–5 cuttings per vine, far below the anticipated rate of 8–18. This made it hard to achieve the targets.

During a meeting in Entebbe in June 2010, project staff tried to estimate multiplication rates under different agroecologies. The rates ranged from 17.9 for a spreading variety such as 'Polista' to 8.4 for a non-spreading variety such as 'Jewel'. Maximum multiplication rates can only be achieved with good soil, irrigation, fertilization, and dedicated management. It is important to monitor multiplication rates on the ground to support planning and timing of dissemination. There was no rain in the October/November 2010 planting season, so beneficiaries did not want the planting materials. The materials were recycled in January 2011, and disseminated in March/April 2011. As a result, DVMs were reluctant to conserve their beds for the subsequent dry season and several dropped out.

RMT was risky because of the fluctuating demand during dry seasons. In March 2011, after the first season of multiplication, the project still recommended using conventional, rain-fed multiplication from November to December so DVMs could produce roots between November and February (when the demand for roots is high), and therefore spread their risks if demand for vines was lower in February–March. Six DVMs put a total of 6.85 acres (2.5 ha) under conventional multiplication (Laizer 2012). At the end of the project, 69% of the DVMs still produced vines: 34% using RMT, 61% with conventional multiplication, and 5% with a combination of both.

The highest demand (and price) for planting material occurs during a short window of 2–4 weeks at the start of the rains. After this, farmers can get material from sprouting roots left over from the previous season. So it is important to plan the seed multiplication cycle so that farmers get planting materials at the right time.

In the Kinga Marando project, now being implemented in the Lake Zone, DVMs were selected strategically to minimize the effects of the long dry season. Funds were allocated to provide DVMs with net tunnels, irrigation equipment, and new training materials, which have refined tools for planning multiplication and dissemination. CIP is testing new technologies to increase the multiplication rate of sweetpotato (e.g., with sandponics in screenhouses).



Sweetpotato with SPVD on left; healthy plant on right.
Photo by Richard Gibson.

7. Lessons

NARIs need consistent and sufficient investment to maintain a program of multi-locational testing so that varieties can be validated with farmers before starting mass distribution. Vine multipliers should host yield trials and demonstrations of varieties to provide quick feedback on potential market demand. The national varietal release process needs to be strengthened.

Before selecting and training vine growers, a project needs to establish the business case for a sweetpotato vine enterprise (alone or combined with root production, or high-value vegetables). The seed and root segments of the value chain must be linked.

Giving away vines or subsidizing them distorts the market for seed, and may destroy the business of the people who are already producing and distributing vines for sale.

Planting material has to be free of virus, and project quality control needs to screen for viruses in the system. New techniques like net tunnels can help, although farmers need training to be able to use them.

Piggy-backing a seed system from one crop (sweetpotato) onto another (cassava) may not work, especially if the two crops have different requirements, and will rely on different people to multiply them.

To design a gender-equitable seed delivery system for smallholders, an organization needs to know the crop cycle and what farmers need for vine multiplication (land, labor, irrigation, knowledge, cash, and seed). Do the communities have existing groups? Do they have the resources to produce seed, and can they work together effectively? Gathering and analyzing these data require a research team experienced in qualitative methods, in seed systems, and gender. Questionnaire surveys are inappropriate for scoping studies (McEwan and David 2012). Avoid overestimating the capacities of collaborating institutions.

DVMs do not systematically pass on information to neighboring farmers. However, village-level multipliers are so close that farmer-customers can see the quality of the vines in the field although more distant multipliers may be able to produce larger amounts of vines.

There is no point convincing farmers to buy vines that are not available. Production and communication need to go hand-in-hand, though this is easier said than done. Activities to promote varieties and seed should take place alongside vine distribution, and need to be carried out for at least three consecutive growing seasons.

References cited

- Adam RI. 2014. Gender and the Dynamics of Production and Distribution of Sweetpotato Planting Materials Among Small Holder Farmers in the Lake Victoria Zone Region, Tanzania. PhD thesis, Pennsylvania State University, State College, PA.
- Benjamin M, Badstue L. 2010. Sweetpotato knowldege, attitudes and practices in the Lake Zone, Tanzania. Nairobi: HKI
- Benjamin M, Badstue L, Dillon CN. 2010. Sweetpotato knowldege, attitudes and practices in the Lake Zone, Tanzania. Nairobi: HKI.
- CRS. 2012a. SASHA Marando Bora Final Technical Report. Dar es Salaam: CRS.
- CRS. 2012b. SASHA Marando Bora Year 3 Annual Report. Dar es Salaam: CRS.
- CIP, BMGF. 2009. Sweetpotato Action for Security and Health in Africa (SASHA) Project Proposal. Nairobi: CIP.
- Jeremiah SC, Kulembeka HP. 2007. The role of community based organisations, NGOs and farmers in technology transfer. Presented at the XIIIth Triennial Symposium of the International Society for Tropical Root Crops held in Arusha, Tanzania.
- Kapinga RE. 1995. Sweetpotato in Tanzanian farming and food systems: Implications for research. Nairobi: CIP.
- Laizer L. 2012. SASHA MB final technical report. Mwanza, Tanzania: CRS.

- Lembris L, Walsh S. 2012. Seed system lessons learned from Marando Bora in Lake Zone, Tanzania. Dar es Salaam: CRS.
- Low JW, Arimond M, Osman N, Cunguara B, Zano F, Tschirley D. 2007. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. *Journal of Nutrition* 137:1320–1327.
- Mafuru J. 2009. Rapid Market Catchment Analysis for Mwanza Urban Market. Mwanza, Tanzania: Lake Zone Agricultural Research Institute.
- Mafuru J, Kibura J. 2009. Supply chain analysis for OFSP varieties in Mwanza and Kagera Regions, the Lake Zone, Tanzania. Mwanza: Lake Zone Agricultural Research and Development Institute.
- McEwan M, David S. 2012. Sweetpotato Action for Security and Health in Africa (SASHA) Marando Bora: Testing delivery systems for the distribution of quality sweetpotato planting material at scale. Case study material. Gender and Agriculture Community of Practice in Tanzania. Dar es Salaam.
- Mukasa SB, Rubaihayo PR, Valkonen JPT. 2003. Incidence of viruses and virus like diseases of sweetpotato in Uganda. *Plant Disease* 87:329–335.
- Namanda S, Gibson RW, Kirimi S. 2011. Sweetpotato seed systems in Uganda, Tanzania, and Rwanda. *Journal of Sustainable Agriculture* 35:870–884.
- Okello J, Sindi K. 2014. Promoting farmer access to healthy planting material of nutritionally enhanced vegetatively propagated crops: Experiences from a sweetpotato project in Tanzania. Nairobi: CIP.
- Okello J, Sindi K, Shikuku K, Nakazi F. 2013. From Scale to Impact: Effects of the Marando Bora Sweetpotato Seed Multiplication and Distribution Project in Tanzania. Draft Endline Survey Report. Nairobi: CIP.
- Potts MJ. 2006. Large-scale Deployment of Improved Sweet Potatoes in sub-Saharan Africa 2003–2006. Final Report to GTZ. Kampala, Uganda: CIP.
- Sindi K, Kiria C. 2011. Understanding sweetpotato seed systems in Tanzania. SASHA. Nairobi: CIP.
- Sindi K, Wambugu S. 2012. Going-to-scale with sweetpotato vines distribution in Tanzania Marando Bora Baseline Study. Nairobi: CIP.

CHAPTER 7

Delivering clean sweetpotato vines in Rwanda

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Abstract

In 2013–14, the Super Foods project in Rwanda distributed more than 1 million sweetpotato vines as planting material and 24,000 plantlets multiplied in TC. Project IPs produced more than 9 million cuttings. The project helped each farmer group to build at least 2 net tunnels (for a total of 39). Rwanda has two rainy seasons, so sweetpotatoes can be grown year-round. Yet this also favors the buildup of viruses. The project developed a seed system that started with TC in vitro (to clean the plants of viruses), followed by hardening in screen tunnels, before multiplying vines and sharing them with FGs to do the secondary and tertiary multiplication. The project made several new sweetpotato varieties available to farmers, including OFSP ones. Project farmers increased their yields from 6 or 7 t/ha to 12 t/ha. The FGs planted vines in tunnels, then in open fields; no local traders were involved in the distribution. HH bought few vines but gave many away. The project found that the vines rapidly became infested again, so disease-free vines had to be constantly fed into the system to flush out viruses. The net tunnels had to be kept near the homes of responsible people, could be managed at the local level, and were appropriate for a land-scarce country. Links with agro-processors helped to maintain farmer interest in good seed.

Rationale

When the Rwanda Super Foods project was designed, white- and orange-fleshed sweetpotatoes were being repositioned in the Rwandan consumer market because of the projected increased demand for food, government support for agro-processing, and efforts to combat vitamin A deficiency. This project aimed to test different innovations for the sweetpotato product value chains and determine their pro-poor impact.

The project addressed the question of how the poor—particularly women—could capture the benefits of increased sales of staple crops such as sweetpotato. Strengthening the sweetpotato seed system was critical. The project aimed to understand whether commercial seed systems might emerge

in Rwanda, as the Super Foods project created demand for roots for agro-processing (CIP and BMGF 2009).

Getting new, disease-free planting material into the system to flush out the diseased material is not easy. In Rwanda, earlier interventions had supported capacity strengthening for in-vitro plantlet production (CIP and ASARECA 2013). Clean seed is preserved in a TC laboratory or screenhouse at research stations, which typically maintain small amounts unless there is project funding. Private sector participation in sweetpotato seed is limited, as many farmers conserve their own vines year after year and vines are easy to share among farmers.

One solution was to improve the quality of the planting material distributed to farmers while improving the smallholder's ability to maintain disease-free planting materials for a long time. That required strengthening a seed system where the research institute built up enough stock of the required varieties, assuring that they are virus-free and then multiplying them under protected conditions. The sweetpotato seed system also required developing the capacity to deliver clean planting material to secondary multiplication plots near farmers' fields or markets.

1. The intervention

Vines were multiplied and distributed with the support of the Rwanda Agriculture Board (RAB) and CIP staff. From June 2013 to June 2014, the project distributed 750,600 cuttings in the north and 372,381 cuttings in the south of the varieties 'Gihingumukungu', 'Cacearpedo', 'Vita' ('Naspot 9'), 'Kabode' ('Naspot 10'), 'Terimbere', and 'Ndamirabana'. Over the life of the project, more than 24,000 plantlets were multiplied in TC at the RAB Rubona station, and more than 8 million cuttings were produced from primary multiplication for project partners. A further 1,199,200 cuttings were distributed to second-tier partners like NGOs, local governments, and large-scale private growers; 9,199,200 cuttings were distributed in total.

To ensure that the groups kept multiplying fairly clean planting materials after the project phased out in June 2014, each farmer group was helped to build at least 2 net tunnels, each with a different variety (FGs built a total of 39 tunnels). Before introducing the tunnels, 40 farmer representatives were trained to build and maintain them. Urwibutso Enterprises built 3 tunnels to serve contracted farmers, and RAB made 3 for basic seed preservation. The project supplied the anti-aphid netting; the recipients provided the labor and local materials. The project erected 20 signposts on the road near each group, with the name of the group and the main contact person's telephone number. These two strategies were effective because six months after the project ended, the groups were still supplying OFSP vines.

Theory of change

In response to new demand for sweetpotato roots from agro-industry (e.g., biscuit-makers) and the availability of planting material, farmers would begin to grow the new varieties— especially OFSP—to supply the agro-processor. OFSP varieties would be further promoted through media and agriculture and health extension services to rural communities, stressing the nutritional value of the vitamin A-rich, orange-fleshed roots. The model seed system would supply virus-free vines of new varieties, produced on-station (in TC, screenhouses, etc.). Organized FGs, with a high percentage of women participating, would be trained on how to conserve and multiply the new planting material and then distribute it to

neighboring farmers (either by gift or by sale). Virus-free planting material would help to increase the yields of roots. Permanent change would require a consistent demand for roots at prices attractive to farmers, who would be willing to pay for clean planting material.



Framework: Sweetpotato in Rwanda

Stakeholder	Availability / supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Policymakers						There were no government seed regulations
National research		RAB produced in-vitro seed				RAB provided clean seed
International research	Project led by CIP	Created FGs: DVMs	Project did not recover costs of vines	Promoted OFSP biscuits at ag. Fairs and on radio & TV	Provided new OFSP varieties	CIP also provided clean seed
Traders (local markets)	Project ignored them					
Private seed sector		Contract farmers did some secondary multiplication				Trained in disease management
Farmer organizations	DVMs often gave away vines	Often gave vines for free to neighbors	Most vine sales were donor funded	Received training in seed & disease management		Net tunnels managed by responsible farmers. Virus re-infection is a problem
NGOs		CRS, Imbaraga, & YWCA sold or gave vines to DVMs	Some NGOs bought seed			
Private sector processors			Biscuit-maker buys OFSP			
Seed users	Farmers often give away vines for free	Users said vines were already easy to get				

YWCA = Young Women's Christian Association.

2. General context

Sweetpotato is an important food security crop in Rwanda, grown mainly by women to eat at home and to sell (Ndirigwe 2006). The crop is cultivated throughout the country, especially in the densely populated central plateau (mid-altitude) and Bugesera (low altitude) (Ferris et al. 2002). Sweetpotato has low input requirements, is easy to grow, and produces in unfavorable weather in poor soil (Bouwkamp 1985). Sweetpotato is eaten boiled and as a snack. By calories, Rwandese diets consist of beans (22.3%), sweetpotatoes (21.6%), cassava (14.2%), bananas (14.1%), true potatoes (11.9%), and maize (8.6%) (PSAR 2002). Sweetpotato provides employment to youth and women (Ferris et al. 2002), and is sold by smallholders in weekly local markets. In Rwanda, sweetpotato is a crucial food due to an epidemic of African cassava mosaic disease and banana bacteria wilt (Bashaasha et al. 1995; MINAGRI 2007).

Over the last decade, sweetpotato production has increased in Rwanda, where in 2000 production was estimated at 1,000,000 t, making Rwanda one of the biggest producers in East and Southern Africa (Ferris et al. 2002). Fresh root yields of 25–30 t/ha are achievable under experimental conditions compared with on-farm yields of 6–7 t/ha (FAO 2002; Ndirigwe 2006, FAOSTAT 2010).

Farmers in Rwanda grow many varieties, usually two to six in the same field to satisfy their preferences, prolong availability, and reduce risks (Tardif and Rwalinda 1993). Recently, OFSP varieties have been introduced to combat vitamin A deficiency, which is currently estimated to affect 39% of children under 5 years. The sweetpotato program is now promoting high-yielding OFSP with various projects (e.g., Improvement of farmers' access of sweetpotato quality planting materials, HarvestPlus, Agriculture Technology Development and Transfer, and CIP projects).



Net tunnels work best when located near the home of a responsible person.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY

3.1.1 Before the intervention

Landholdings in Rwanda are tiny: The average area cultivated per surveyed HH was 0.43 ha, with sweetpotato occupying 0.08 ha.

There is a lack of improved varieties and clean planting material. Rwanda has two rainy seasons, so the crop can be grown throughout the year. Therefore, planting material (vines) can be easily obtained from mature crops. But growing sweetpotato throughout the year increases the build-up of viruses, which depresses yields. Rwanda's sweetpotato yields of 6–7 t/ha are far below the world average of 14 t/ha. The lack of improved varieties over the past 10 years has reduced sweetpotato production by 40% in Rwanda, where few sweetpotato farmers have access to improved varieties that are high yielding and disease resistant. Some farmers hesitate to take up new varieties (e.g., OFSP) that have low to medium dry matter content and poor storability, even if they are higher yielding.

Farmers save their own seed or get it from other farmers or from the local market. They may also acquire seed as relief supplies from the government, NGOs, or international agencies after war or failed seasons, or due to poverty. There are no designated seed producers. Most old planting material is diseased and has low yield potential. In areas where there are long dry spells, vines may be lost and farmers fail to get planting material. Various systems have been tried by NGOs and farmer cooperatives, but these modest efforts collapse when the projects end.

The SASHA Rwanda Super Food project baseline was conducted in 2011, in two regions (north and south). Few farmers knew of vine multipliers; men and women got most of their vines from their own farm. The second major source of vines was neighbors, especially females.

The most common way to preserve vines is to leave part of the sweetpotato plot unharvested; the second method is to plant sweetpotatoes in low wetlands. Less popular methods included keeping vines under the shade, planting sweetpotato near the bathroom, and burying the vines under the ground. About 56% in the north and 25% in the south bought planting material.

Most farmers said that vines were readily available. In the north, 76% female respondents indicated that getting vines was not a problem, and 83% of the males agreed. In the south, 64% and 38% of male and female respondents, respectively, had no problems getting sweetpotato vines.

In the north, 40% and 35% of males and females, respectively, planted new varieties of sweetpotato in last five years. Farmers got the new varieties from nearby farmers, extension agents, distant farmers, and research stations.

In the north, 71% and 70% of the male and female HH heads gave sweetpotato vines to non-family members. In the south, 57% and 56% shared vines with other families.

At baseline, there was little sale of sweetpotato vines in the study regions. Among the 573 farmers interviewed, only 31 sold any vines during 2010/11. Of those who did, 28 were in the north and only 3 were in the south. Only three women sold vines.

More females received information about sweetpotato than did males in both regions. Just over half of the women in the study HH in the north received advice about sweetpotato (from NGOs, extension agents, or fellow farmers).

3.1.2 What changed as a result of the intervention

The formal seed system that was developed goes from the TC lab at RAB's Rubona station to seed multipliers to roots producers. This includes in-vitro production of plantlets; hardening in screenhouses (pre-basic seed) and open-field multiplication for primary (basic seed), to tertiary seed (QDS). Basic seed is managed by RAB, while FGs and contract farmers manage secondary and tertiary multiplication. By the end of the project, 4,105,700 cuttings were produced and distributed to partners, NGOs, and local government (RAB 2014). Assuming that farmers at secondary and tertiary sites shared cuttings with at least one neighbor, more than 8 million cuttings were distributed by the end of the project.

New varieties were introduced to the multipliers. The market for orange roots has increased the demand for vines. OFSP roots are supplied to restaurants in Kigali, embassies, and private and public institutions, and although these are hardly the target market for vitamin A-rich sweetpotatoes, such elite distribution is valuable publicity and contributes to changing the perception that sweetpotato is a low-status food. Local policymakers accepted sweetpotato as a priority crop in some districts and provided land for vine multiplication. Farmer group multipliers are selling OFSP vines to local governments, farmers, and NGOs. Farmer groups sold more than 1 million cuttings (Table 7.1).



Root farmers, like Drocella Yankulije, depend on vines to grow their sweetpotatoes.

Table 7.1. Sweetpotato vines sold by farmer multipliers and their value

Vine multiplier	Number of cuttings sold per year			Total	Total Value (USD)
	2011/ 2012	2012/ 2013	2013/ 2014		
Farmer groups backstopped by YWCA	0	160,142	193,288	353,430	1,971
Farmer groups backstopped by Imbaraga	54,700	218,334	393,031	666,065	4,330
Individual farmers linked to SINA	0	0	30,000	30,000	214
Total	54,700	378,476	616,319	1,049,495	6,516

Source: Database of vine sales by groups and farmers. Exchange rate: about 700 Rwf = US\$1 in 2014.

In the endline survey, the percentage of HH selling vines remained small, only 2% selling or buying. Vine sales were a farmer group activity, managed in group plots, with the money going to the group.

3.2 AFFORDABILITY OF THE NEW SEED

Sweetpotato seed is sold at 3–5 Rwf (\$0.004–0.007) per cutting. In 2015 the tender committee at RAB revised the price of one cutting up to 10 Rwf (\$0.014). Table 7.2 shows the number of cuttings sold to different types of buyers during the Rwanda Super Foods project.

Table 7.2. Number of cuttings sold per type of buyer

Type of buyer	Number of cuttings sold	Percent (%) of total cuttings sold
Farmer groups	15,242	1.5
NGOs	715,305	70.2
Government institutions	61,000	6.0
Individual farmers	217,414	21.3
Farmer cooperatives	10,534	1.0
Total cuttings	1,019,495	100.0

Source: Monitoring data records on vine sales, Rwanda Super Foods project.

NGOs buy most of the vines and give them to their beneficiaries for free. Sales are expanding, but they are donor financed. During the project, sweetpotato yield almost doubled, from 6–7 t/ha to 12.8 t/ha (Table 7.3).

Table 7.3. Yield data from crop cuts in farmers' fields

Variety	Highest yields (kg/ha)	Average yields (kg/ha)
Cacearpedo	19,366	12,540
Vita (Naspot 9)	18,606	13,280
Kabode (Naspot 10)	19,578	15,447
Gihingumukungu	16,529	12,576
Local variety	15,849	10,286
Mean		12,826

Source: Data from crop cut exercise, 2013; representative project farmers growing varieties distributed by the project and existing landraces.

The average yield for four sites was 15.4 t/ha and 13.3 t/ha for 'Kabode' and 'Vita', which perform better than other varieties. Average yield for the local variety was the lowest, but the yields of local varieties were higher than the baseline averages. This indicates that better crop management and clean planting material contributed to yield increases of local varieties.

3.3 SEED QUALITY

3.3.1 Before the intervention

The major sweetpotato pests in Rwanda are viruses and weevils. Njeru et al. (2006) reported that although most farmers (73%) in Rwanda could identify SPVD as the most damaging disease, most (65%) were not aware of what causes the disease. Laboratory testing of more than 300 fields revealed that 83% of symptomatic plants and 31% of asymptomatic ones were virus infected, with mixed infections common in symptomatic plants (Njeru et al. 2008). The SPVD complex, caused by mixed infection of sweetpotato feathery mottle virus and sweetpotato chlorotic stunt virus, is by far the most destructive viral disease of sweetpotatoes in Africa and perhaps worldwide (Carey et al. 1999). The use of planting material from the previous crop and the abundance of weeds (a reservoir of viruses and vectors) make the disease difficult to control (Karyeija et al. 1998).

At baseline, most respondents in the north (88%) and south (91%) said that they removed tired-looking plants from the field once they noticed them; which is a good practice since it keeps the virus from spreading. Most farmers in both regions also practiced fallowing and crop rotation (sweetpotato followed by two seasons with another crop), which is another way to manage diseases and pests.

3.3.2 What changed as a result of the intervention

The project established a “flush-through” system of material derived from TC distributed to the multipliers at least every season, except for farmer multipliers with net tunnels, who maintained clean planting materials for one to two years. Providing disease-free planting material and training farmers on vine maintenance doubled the yield of sweetpotato roots by project farmers, from around 6–7 t/ha at the start of the project to about 12 t/ha. By the end of the project in 2014, most farmers producing roots or vines still had planting materials in good condition, which they had conserved themselves.

4. Seed producers and seed availability

4.1 THE MODEL

The Super Food project implemented a system of DVMs (i.e., individual farmers or groups with access to water and willing to multiply sweetpotato vines to distribute to the community). However, even with the DVMs, viruses easily infected the seed because it was difficult to isolate the multiplication plots from other sweetpotato plots. To avoid diseases, the clean vines had to be kept isolated from insect pests. The project introduced net tunnels to do this.

One of the project objectives was to compare two value chains: one of individual farmers supplying roots to the food processor SINA, and a second one based on FGs supported by two NGOs: the YWCA and Imbaraga (the national farmers’ cooperative union). The project had three individual multipliers who supplied SINA and 42 farmer group multipliers supported by NGOs.

RAB received virus-free TC plantlets from KEPHIS. RAB then multiplied TC plantlets, hardened them, and used them to produce cuttings in screenhouses. The cuttings were sold or distributed to the individual and farmer group multipliers who were provided with net tunnels. RAB multiplied primary and secondary materials in the open field at their research stations to supply FGs. RAB produced on average 4,000 clean plantlets per month of at least four OFSP varieties and a white-fleshed one, ‘Ukerewe’, which KEPHIS had also cleaned up.

Most groups practiced the 1-2-3 approach of vine multiplication. That is, for the first stage they produced clean planting material in the tunnels. For the second stage, they cut the materials from the tunnels and planted them in open, secondary multiplication plots using the RMT of 20 x 10 cm spacing with three-node (20 cm) cuttings. At the third stage, this material was harvested and planted under conventional multiplication for both vines and roots. The FGs sold the planting material or used it to



A clean seed system based on groups of DVMs. Marie Claire Mukakimenyi shows off a healthy vine.

Photo by S. Quinn.

grow roots. Individual farmers also produced roots, and conserved their vines using conventional methods.

CRS was responsible for transporting and distributing vines from RAB to the FGs. They also provided training on nutrition to Imbaraga and YWCA staff. With support from CIP, the NGOs trained the FGs on agronomic and seed practices. No local traders were involved in this distribution.

Vine movement during 2013/2014. HH surveyed at the endline had bought and sold few vines, but gave many away. Of HH surveyed, 55% gave or exchanged vines and 62% received vines for free or bought them. Project participants shared more vines than control HH, probably because the project continued to supply quality vines to participants (Table 7.4).

Table 7.4. Sweetpotato cutting movement by level of participation

	Control	Individual	Imbaraga	YWCA	Spillover	Total
1	Number of times sweetpotato cuttings given out or sold by per HH during 2013/2014					
N	108	23	114	76	145	466
Mean	2.81	4.22	3.83	3.51	3.28	3.39
Median	2.00	4.00	4.00	3.00	3.00	3.00
2	Number of times (transactions) vines are received or bought per HH					
N	98	20	85	86	240	529
Mean	2.64	3.45	3.54	3.14	2.91	3.02
Median	2.00	4.00	4.00	3.00	3.00	3.00

Source: Rwanda Endline Survey, September 2014.

Control HH received more material (70 kg/HH), suggesting that informal transactions involve lots of planting material. Median values for participant HH ranged from 43 kg/HH to 60 kg/HH, with much of that supplied from groups. Spillover HH (farmers who received vines from group members but not directly from the project) received a median value of just 30 kg, most of it from groups (Table 7.5).

Table 7.5. Cuttings (in kg) received per HH (gifts or purchases) 2013/2014

Category	Number	Average	Minimum	Median	Maximum
Control	97	100	0.07	70	423
Individuals to Sina	20	87	0.10	60	630
Groups with Imbaraga	85	168	0.10	43	8,958
Groups with YWCA	86	85	0.07	44	1,087
Spillover	239	66	0.34	30	2,062
Total	527	92	0.07	43	8,958

Among HH distributing vines (for free or for sale), control HH and HH in groups backstopped by the YWCA or individuals supplying SINA had median values of 60 kg/HH. Those groups backstopped by Imbaraga had a median value of 44 kg, with spillover HH having given out 30 kg.

4.2 BENEFITS FOR THE FARMERS

The principal advantage of receiving high-quality planting material of improved varieties is higher yields. According to the endline survey, participating female and male growers produced over two times more sweetpotato than control HH (Table 7.6). Participating female growers (85%) and 76% of males sold sweetpotato, compared with only half of control growers.

Table 7.6. Sweetpotato Produced and Sold by Gender

Group	Sample Size	Total produced (mean kg/HH)	Sold (mean kg/HH)	Production sold (%)	Value of Sales (\$/HH)	Value of Production (\$/HH)	Proportion of HH Selling SP (%)
Control	119	409	13	32	18	58	50
Control Male	88	333	15	47	20	44	49
Participant	247	1118	41	37	83	223	85
Participant	80	1099	39	36	72	198	76
Spillover	220	487	15	31	28	89	65
Spillover	92	750	26	36	44	123	54
Total	846	731	22	36	34	95	67

*Source: Reported production and sales data by plot by season for 2013–2014 from Rwanda Endline Survey.

4.3 QUALITY ASSURANCE

To produce planting material free of viruses, pathogen-tested plantlets were micro-propagated at laboratories in Rubona and Musanze. Mature plantlets were transferred from the lab to the screenhouse for hardening and then transferred to the net tunnels. Once in the farmer's field, the plants were kept healthy by NS—rouging plants with virus symptoms. Training in integrated disease and pest management was provided to lab technicians and to farmer group DVMs.

RAB technicians do not yet have the capacity to conduct enzyme-linked immunosorbent assay (ELISA) tests to determine whether material has remained virus-free. That verification can be done by sending samples to KEPHIS in Muguga, Kenya.

5. Regulation and policy affecting farmers' use of quality seed

At the time of the project, there were no government regulations concerning seed quality. The Super Foods project was a pilot for the benefits of quality seed.

6. Seed multiplication tools and techniques

6.1 MULTIPLICATION METHODS

Rapid multiplication entails preparing a nursery bed and planting cuttings 20 cm long (three nodes), closely together (10 x 20 cm) and a density of 50 plant/m², which discourages root growth. Animal manure or chemical fertilizers increase vine growth. Small areas are also easier to fence to protect from animals. However, rapid multiplication does require significant management, especially during planting. Successful rapid multipliers locate their plots near water, or they have irrigation equipment.

Low-cost vine conservation net tunnels. The net tunnel is a structure 3 m long x 1.8 m wide, covered with the same aphid-proof netting as is used on a greenhouse. The tunnel is completely closed and only opened when vines are cut. Developed and tested by CIP and scientists at the Kenya Agriculture Research Institute's (KARI) substation in Kakamega—a place with high virus pressure—planting materials from several varieties were maintained for 33 months with little or no virus infection.

If trained farmer multipliers could maintain disease-free planting material in the tunnels, they would not have to return frequently to the research station to renew their stocks. Tunnels, however, require management.

There are four kinds of tunnel management: (1) Tunnels built by the groups selecting a natural leader to maintain and manage them for the group, generally at the leader's home. These tunnels, all lasting more than two years, were the best maintained (structural integrity, agronomic practices, and keeping the vines healthy for the longest time). (2) Tunnels near a member's home or near a water source that were managed collectively by the group members. These were average in terms of maintenance and the quality of the vines. (3) Groups with tunnels far from any home and managed collectively by the group. These tunnels were usually poorly maintained and the vine quality was poor. (4) Private tunnels managed by an individual. These had the highest production and were well maintained. But most of these have been in use for only one year, so it is too soon to tell whether they are able to keep planting material clean for at least two years.

Farmer groups had been using net tunnels for 14–22 months when a virus survey was conducted by systematically collecting 163 leaf samples. Only two samples ('Cacearpedo' variety) tested positive for virus from one group. The training on NS and tunnel management enabled the groups to maintain quality vines for a long time.

By the end of the project, out of 18 tunnels built in September 2012, 1 was destroyed, 9 had to have the vines replaced because they were infected by viruses or were not producing well, and 8 were still in good condition, with healthy vines. Nineteen more tunnels were planted between March and November 2013. At the time this chapter was written, all of these tunnels were in good condition, with healthy vines. Most farmers have been able to keep tunnels in good condition for at least one year. When the tunnels were two years old, 95% were in good condition but only half of them had healthy vines. Groups of farmers whose sole purpose is agriculture kept the tunnels and vines in better condition than did groups engaged in several activities. Youth groups were not able to maintain the

vines or tunnels in good condition. Tunnels managed by dedicated individuals were in better condition than the ones managed collectively.

Tunnels were a novelty, and they raised awareness in the rural areas of the need to use clean planting material. After 2–3 months, a tunnel 3 m long by 1.8 m can produce about 1,192 vines (each 30 cm long) per harvest.

Scaling up. What capacities are required?

Infrastructure is essential for scaling up the use of quality planting material:

- 1) TC facilities maintaining verified stock of disease-free materials. This can be a small facility as it is cheaper to multiply cuttings in screenhouses than to use TC micro-propagation.
- 2) An insect-proof facility for hardening.
- 3) Screenhouses for multiplying pre-basic material.
- 4) Decentralized net tunnels.

Scaling up requires trained personnel, at the research station, but also agronomists and technicians who can train farmer multipliers. There was a serious lack of personnel who understood sweetpotato planting material.

Scaling up: Roles and responsibilities

National research programs traditionally had the role of maintaining disease-free plantlets in TC and producing pre-basic material. This role needs to continue, but often these programs cannot produce enough pre-basic material. The private sector should play an increasing role, especially in pre-basic multiplication after hardening.

Public sector extension and NGOs also need to play roles in training and disseminating planting material. Organizing farmers into groups makes training and supervision more efficient.

Wealthier farmers with more land and water (who are accessible to many members of a community) should be considered for training as DVMs. These individuals could evolve into sweetpotato enterprises, with root sales helping to support the investment in quality seed production. As demand for vines is cyclical, and has market risk, the income from roots spreads risk. So in a good year, income from vine sales can be high, but income from roots provides a more stable income. Roots and vines can form a joint enterprise.

7. Lessons

Although the Rwanda Super Foods project ended in December 2014, there is a follow-up project funded by UKAID, called SUSTAIN, that will continue to disseminate OFSP through nutrition programs and value chain development through 2018. This will permit follow-up of the DVMs established during the Super Foods project and enable some of the recommendations emerging from that project to be implemented.

Basic seed must be constantly distributed to multipliers to maintain its quality

Findings: It was difficult for farmers to keep the material clean in the field beyond one season. Through flushing out the infected materials by continuously putting clean planting material into the system, yields increased from 6 t/ha to 12 t/ha. Most of the material was free of virus symptoms for several seasons more.

Analysis: The demand for disease-free planting material outstripped its supply. The national program struggled to meet this demand, in part because their procurement system is slow, and also because TC technicians are not paid according to amount of plantlets produced. There was also much training in NS.

Recommendation: Explore additional approaches to producing larger amounts of quality planting material. Pay more attention to training farmers on how to isolate clean planting material from existing sweetpotato fields. Identify larger-scale growers and TC operators to complement government activities.

Scaling up using net tunnels for vine conservation

Analysis: The tunnels attracted the attention of many in the community. Initially, some screens were cut as curious people wanted to see what was inside. This led to tunnels being moved closer to homes where they could be well supervised. Tunnels became a symbol that the multiplier had been trained and had the new OFSP varieties.

Recommendations: Tunnels should be used by market-oriented groups and individuals who have water and the management skills to maintain the tunnels. Larger tunnels may be better suited for meeting the high demand for quality material. Multipliers should charge more for cuttings coming from the tunnels than for those grown in the open field.

Lesson learned: Tunnels are best managed by individuals, or by solid groups with leadership, water, and a commitment to agriculture.

Link with processor provided stable market for roots which in turn provided consistent demand for quality vines

Experience: The project linked farmers to a private agro-processor (baking novel products such as the “Akarabo Golden Power Biscuits” made from OFSP). The processor was linked to two types of FGs: market-oriented groups in the north backstopped by the NGO Imbaraga, and groups composed of vulnerable HH backstopped by the YWCA in the south. FGs received repeated trainings on vine conservation and on rouging (uprooting) plants with virus symptoms.

Findings: Use of quality vines produced notable yield impacts, with averages of 6 t/ha increasing to 10–18 t/ha. Having a consistent market led farmers to invest more capital and labor into sweetpotato. This resulted in much higher sweetpotato yields among participant HH than nonparticipants.

Analysis: Having a ready buyer of roots encouraged other members of the community to seek out quality vines from FGs. Vine sales by farmer multipliers increased. However, the tradition of giving (not

selling) vines to one's neighbors is still strong; sales are most likely to an NGO or to individuals from outside of the village.

Recommendations: Knowing of a reliable market drives some farmers to seek quality planting material of the varieties of interest to the processor. Those seeking vines often turn to RAB first. For farmers to benefit, a better marketing campaign is needed to promote farmer multipliers as sources of planting materials. The farmer multipliers need to be linked to sources of disease free-planting material, so that they can periodically flush out their material.

Land scarcity

Findings: Rwanda is land-scarce. The vine tunnels needed little land, and so were an acceptable way to introduce RMT to farmer multipliers. Once the vines went to the field for further multiplication, individuals preferred conventional multiplication. Government stations do have more land, so they tend to become heavily engaged in larger-scale multiplication, not only as basic seed multipliers but as secondary multipliers as well.

Analysis: By the end of the project, because of land scarcity, the demand for quality OFSP vines outstripped supply. Group multipliers prioritized keeping quality planting material for their members, and sales of vines to surrounding farmers increased significantly in the last 18 months of the project. Large-scale multiplication on a government station is only viable if there is a project buying this material. There were small-scale multipliers selling vines before the project; they continue to sell vines after the project.

Recommendation: There is now demand for quality vines in Rwanda. Farmers with more land and water should be sought out to be multipliers. Research stations need to establish mechanisms to recover their production costs for seed and set up mechanisms to sell planting material at least at cost. They also need to create a revolving fund so that multiplication can continue when projects end.

The vine market is not 100% guaranteed, but communication did increase demand

Experience: The project had an active communication strategy, promoting the new OFSP-based biscuits at agricultural fairs, on the radio, and even in a television advertisement. This created awareness that a new marketing opportunity existed and that OFSP is better for your health than white-fleshed varieties.

Findings: As most farmers can retain their own vines, the demand for vines is erratic; however, the demand creation strategy created awareness of the high-quality vines. Roadside signs indicated that groups were quality vine producers. Demand for vines began to emerge from non-intervention districts as well as from other parts of the four target districts.

Analysis: Given the land constraints, no farmer or multiplier group wants vines to go to waste, especially high-quality ones. The tradition of giving vines to neighbors at no cost continues, and is a good food security practice of neighbors helping neighbors. There is a need to improve estimates of vine needs to match planting times.

Recommendations: RAB needs to coordinate with extension staff so that planning for vine needs in any district begins at least six months before the growing season. RAB should supply farmer multipliers

who in turn supply their communities. In-kind payment systems should be explored, as should innovative mechanisms that sell more vines yet preserve traditional practice. That might include giving a neighbor 1 kg for free but charging for the next one. Advertise the value of quality vines, to strengthen farmers' willingness to pay. A small video could show increased yields with quality vines on the television, internet, and at agricultural fairs.

References cited

- Bashaasha B, Mwanga ROM, Ocittip'Obwoya C, Ewell PT. 1995. Sweetpotato in the farming and food systems of Uganda. A farm survey report. Kenya, Uganda: CIP-NARO.
- CIP and ASARECA. 2013. Dissemination of New Agricultural Technologies in Africa (DONATA). Transfer and dissemination of proven and emerging agricultural technologies in orange-fleshed sweetpotato. Final Technical Report. Nairobi: CIP.
- CIP and BMGF. 2009. Sweetpotato Action for Security and Health in Africa (SASHA) Project Proposal. Nairobi: CIP.
- FAOSTAT. 2014. Available from (<http://faostat.fao.org/site/339/default.aspx>) (Accessed on 21 Nov. 2014)
- Ferris RSB, Wanda K, Tuyisenge J, Munkankubana D, Kagiraneza B, Ngaboyisonga C, Gatarayihya C, Uwantege C, Kayange C, Butare L. 2002. Sweetpotato Sub-sector market survey Rwanda. ATDT-CIAT/ISAR/IITA-FOODNET and PEARL-Project.
- Minagri. 2007. Annual report. (Available from <http://www.minagri.rw/rapport 2007>)
- Ndirigue J. 2006. Adaptability and Acceptability of Orange and Yellow-Fleshed Sweetpotato Genotypes in Rwanda. MSc. Thesis. Makerere University. 86 pp.
- Njeru RW, Bagabe MC, Nsabimana J, Ndirigue J, Butare L, Kajuga J, Nshimiyimana JC. 2006. Farmers' knowledge on the management of sweetpotato virus disease in Rwanda. Presented at the African Region Meeting on Women in Science for Food and Nutritional Security in Africa held in Entebbe, Uganda, 3–7 July 2006.
- Njeru RW, Bagabe MC, Nkezabahizi D, Kayiranga D, Kajuga J, Butare L, Ndirigue J. 2008. Viruses infecting sweet potato in Rwanda: Occurrence and distribution. *Annals of Applied Biology* 153:215–221.
- PSAR. 2002. Programme d'Appui à la Sécurité Alimentaire du Rwanda, Annual report.
- RAB. 2014. Sweetpotato Programme, SASHA-Rwanda, Semester report, June 2014.
- Tardif D, Rwalinda P. 1993. Situation de la patate douce et le manioc au Rwanda: Réflexions sur leur production, productivité, et leurs perspectives d'avenir dans l'agriculture rwandaise. Minagri/DSA, Publication N° 26, 1993.

CHAPTER 8

Public-private partnerships to multiply seed potato in Kenya

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Abstract

Before the 3G (three generation) project, only certified seed potato could be legally sold in Kenya. This created a great bottleneck, since the public sector was the only source of certified seed; supplies were limited and the seed was expensive. A new technology, aeroponics, allows minitubers to be produced much faster than seed in open fields. The project used aeroponics to produce over 1.2 million minitubers, which in turn were planted in the field twice to produce 900 t of 3G seed in two years. This seed was sold to commercial seed producers and to FGs for further multiplication (4G and 5G seed). Some seed producers also built their own aeroponics units. About 20,000 farmers heard about the seed through demonstration plots, field days, trade fairs, and over FM radio. Seed packs of 5 and 10 kg were made available to allow farmers to experiment with the new seed. Potato farmers responded by buying the entire supply of seed, at market prices. The farmers also learned about new technologies for multiplying seed on their own farms, including PS, NS, and small seed plots. The project convinced the government to relax restrictions on selling QDS, thus allowing the private sector to invest in aeroponics and seed production. Some private companies successfully managed aeroponics units, but the public sector could not keep its units going. Smallholders are interested in quality seed if it can be made available and affordable.

Rationale

The 3G (three generation) innovative seed strategy, funded by the United States Agency for International Development (USAID) and developed by CIP and its partners, delivered low-cost, quality seed potato in three field generations rather than five to seven. This lowered the cost of producing starter seed, and also prevented the build-up of diseases that cause degeneration. The 3G seed strategy produced large quantities of minitubers through an RMT called aeroponics. In Kenya for the first time, private firms played an important role in producing and distributing seed, making the seed potato subsector more efficient.

1. The intervention

Activities components, scale, and scope of the intervention

The 3G seed system was implemented in Kenya, Rwanda, and Uganda, funded by USAID in a project entitled “Tackling the food crisis in Eastern and Central Africa with the humble potato.” This chapter focuses on Kenya, which received 80% of the funding. The project’s goals were to increase the supply of basic starter seed from the public and private sectors and to train smallholder seed multipliers. The intervention aimed to deliver low-cost, high-quality seed to growers in three generations. Aeroponics reduced the multiplication time, lowered the production cost of starter seed, and decreased the build-up of diseases leading to degeneration. Interventions included (1) capacity building of the national program, (2) co-funding private-sector initiatives to produce seed, (3) promotion and distribution of quality seed to trained secondary seed multipliers and smallholder ware potato growers, (4) dissemination of high-yielding and disease-resistant varieties, and (5) training of smallholders to use PS (choosing the best plants for seed) to maintain their seed (Figure 8.1).

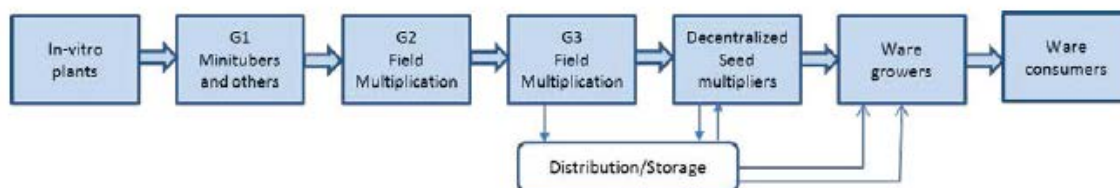
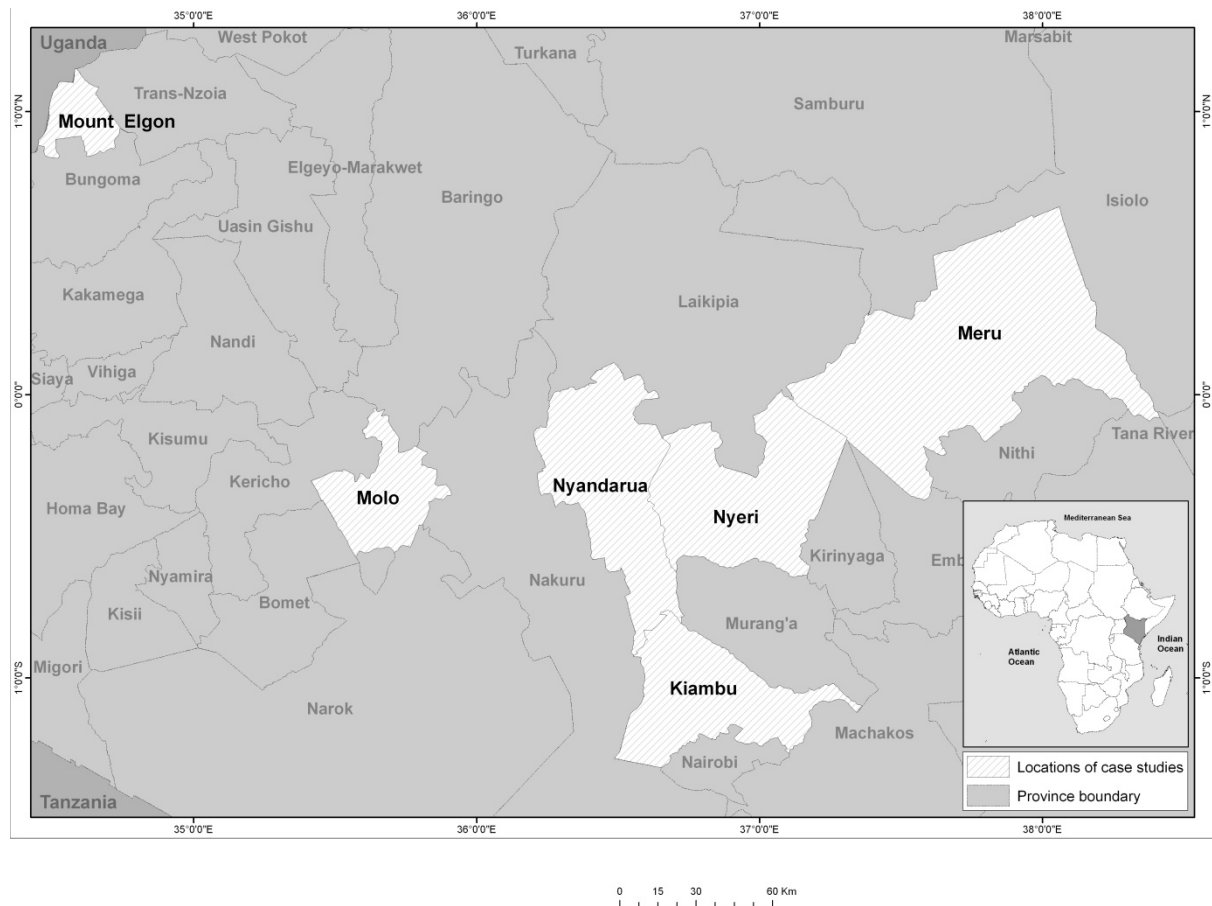


Figure 8.1. Conceptual scheme of the intervention. Source: Authors.



Theory of change

The assumption was that Kenyan potato farmers had a great, unfulfilled demand for good seed of improved varieties, available on time (Gildemacher et al. 2009; Ayieko and Tschirley 2006). Only certified seed could legally be sold in Kenya. The bottleneck was the public sector, which was responsible for producing certified seed but could meet only a fraction of the demand. A new public-private partnership (PPP) would use new technology to produce much more seed. Private sector seed producers would be linked to new customers: ware potato producers who would be trained to use this seed, and to select for good seed on their own farms.

Up-scaling perspectives, achieved objectives, and impact

The strategy was appropriate for east Africa, where arable land is scarce, degeneration of seed through disease is rapid, and formal seed is too expensive for smallholders. There was rising demand for potato and opportunities for private sector seed producers and multipliers.

Aeroponics produced quality seed more quickly and in larger quantities than previous efforts. The project produced more seed than was proposed. The amount of 4G seed in Kenya reached about 2% (of

total seed planted) at the end of the project in 2011—up from about 0.3% at the start of the project in 2008.

Framework: Potatoes in Kenya

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Policymakers	QDS increased supply		QDS lowered prices			Agreed to accept QDS
National research	provided some source seed	Sold certified 3G seed to producers			Collaborated on plant breeding?	
International research	Trained govt. & farms on aeroponics		QDS and aeroponics allowed lower costs	Project advertised seed on radio	New, improved varieties	
Traders (local markets)		Seed producers did the trading				
Private seed sector	Commercial farms invested in aeroponics to provide pre-basic and multiplied to provide basic seed		Some growers buy 3G seed & multiply it			
Farmer organizations	Many women participated in FGs	Farmer groups received training	Farmers could afford to buy seed			Groups trained in PS and NS
NGOs		NGOs, KARI, & govt. extension trained farmers		Trained farmers on importance of quality seed		
Private sector processors			Active market in tubers encourage s potato crop		Demanded commercial varieties	Implicit market demand for quality
Seed users		Buy 4G and 5G seed from seed producers				

2. General context

Farming system in Kenya

Most potatoes in Kenya are grown at high altitudes, from 1,500 to 3,000 masl, by some 800,000 farmers on about 108,000 ha; roughly 70% of potato growers have less than 1 ha of land (Kaguongo et al. 2009). Yields average 7.7 t/ha. Potato farmers also produce cereals and legumes. Crops are usually rotated after two or three seasons. Kenyan potatoes are produced for the domestic market, with three-quarters of urban HH eating them regularly (Kaguongo et al. 2009; Gildermacher et al. 2009). Soil fertility is declining due to continuous cultivation without applying fertilizers. Most potato-producing areas in Kenya have a bimodal rainfall pattern and can produce at least two rain-fed crops a year.

Market importance of potato

Potato has several advantages over grains. It has a short cropping cycle, with high returns to land and labor, offering a high potential to improve smallholders' livelihoods (FAO and CFC 2010). Potato is Kenya's second most important food crop after maize. Annual production is worth about \$300 million at the farm gate (MoA 2009). The industry employs about 2.5 million people as market agents, transporters, processors, vendors, retailers, and exporters. Some 60–65% of the fresh potatoes sold in the cities are processed in restaurants and street stalls (ECAPAPA et al. 2005; Kirumba et al. 2004).

The seed potato sector in Kenya

Potatoes in Kenya have low yields of less than 10 t/ha. But farmers who use the best technologies reach 25 t/ha. This difference has been attributed to low-quality seed, low-yielding varieties and poor disease management (Olanya et al. 2001). Certified seed potato meets less than 1% of Kenya's 30,000 tons' annual requirement, mainly due to limited production and storage capacity (Ayieko and Tschirley 2006).

Certified seed potato was also expensive, so most farmers planted seed from other sources (Mureithi 2000). A 50-kg bag of certified potato seed cost about US \$30, and a farmer needed about 16 bags to plant 1 acre (4,000 m²) and costing about \$480, or about half of the total production costs. More than 95% of the farmers obtained seed from their previous harvests, from neighboring farmers, or from the local ware markets.

Trends, developments, and ongoing change of context

The Agriculture Development Cooperation (ADC) and KARI produced seed potato; however, after the 1990s rearing seed became a challenge due to reallocation and subdivision of ADC and KARI farms. There was no well-defined mechanism for disseminating new varieties. KARI began producing certified seed through contract farmers. ADC provided certified seed after getting starter material from KARI.

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

Most farmers did not understand the concept of certified seed. But they noticed seed degeneration. When a variety began to yield less, farmers explained that it was because the variety was “used to” or “too familiar” with the soil. So farmers would seek seed from another area, exchanging seed with neighbors, or moving their potato plots (Ng’ang’a et al. 2003). Farmers planted the smallest tubers as seeds and ate or sold the bigger ones.

Farmers saved their own seed to save money and because they trusted the quality of their own seed; having farm-saved seed made it easier to plan production (ibid.). The basic seed potato produced by the National Potato Research Centre (KARI/Tigoni) was mostly sold to farmers who produced ware potatoes in neighboring districts (KARI 2008). The supply of certified seed was limited and expensive. Producing pre-basic minituber seeds from in-vitro plantlets was slow and led to bottlenecks in supplying certified seed (Muthoni et al. 2010). KARI/Tigoni planted the minitubers in the field, replanting the harvest for up to three generations to produce basic seed which was distributed to contract farmers, ADC, and other KARI stations. Seed planted for several years without replacement resulted in the build-up of pests and diseases (Kabira et al. 2006).

The seed distribution system was poorly defined. Basic seed potato was produced only by KARI, with an annual production of 35–80 t. Areas close to KARI/Tigoni and ADC/Molo had no problem accessing this seed. Farmers further away, however (e.g., Taita Taveta and Mount Elgon), had to travel long distances to get these seeds—about 142 km to buy certified seed, 37 km to get clean seed, and 18 km for positively selected seed (Kaguongo et al. 2009). Farmers had little knowledge of seed availability or the benefits of quality seed. Neighbors were the major source of information about new varieties, and the community served as the seed bank for farmers when they needed seed. Farmers sometimes sought seed to get a new variety (Obado 2010) or because of seed degeneration, disease, and loss to floods or drought.

3.1.2 What changed as a result of the intervention

Increase in certified seed production

With aeroponics, in less than two years (March 2010–August 2011), more than 900 t of 3G seed was produced in Kenya. The seed of these market-demanded varieties was produced by high-grade seed producers, including Kisima Farm, Milwar Farm, ADC/ Molo, Kagia Farm, and Stephen Chege’s Farm. All the 3G seed was sold to secondary seed multipliers: trained farmers, groups, and institutions such as agricultural training centers and secondary schools, which multiplied the seed into 4G and 5G. Decentralizing seed production, coupled with large amounts of 3G seed, eased the pressure on KARI. With farmer’s seed demands satisfied, KARI/Tigoni could give large amounts of basic seed to ADC/Molo to multiply into certified seed. KARI/Tigoni increased its production of basic seed to a record 150 t in 2011.



A well-run commercial farm can be a good place to multiply large volumes of seed. Harvesting potatoes on Kisima Farm, Kenya.
Photo by Kisima Farm

Accelerated diffusion of newly released varieties

The newly released varieties (‘Kenya Mpya’, ‘Sherekea’, and ‘Purple Gold’) were rapidly made available to farmers in sufficient amounts. Farmers could access certified seed of ‘Kenya Mpya’ within 1 year. The variety was released in May 2010, and certified seed was available in March 2011. Making seed available so soon, before the variety starts to degenerate and lose its yield potential, is one of the projects’ greatest achievements. Aeroponics could revolutionize the potato industry. This project produced over 1.2 million minitubers in just 2.5 years with a multiplication rate of 20–62 tubers per plant. Annual minituber production was now 10 times greater than before t



Minitubers, grown by aeroponics.
Photo by CIP

Seed distribution channel

Farm Inputs Promotions Africa Ltd (FIPS-Africa) established a network of promoters to sell seed potato and to train farmers in six districts: Nyandarua, Nyeri, Meru, Kiambu, Molo, and Taita. FIPS-Africa reached more than 10,000 farmers who bought 60 t of 3G seed potato packed in 5- and 10-kg bags supplied by Kisima Farm in three seasons. FIPS-Africa pioneered and ensured distribution of large amounts of seed potato in small, trial packs to thousands of smallholders.

Awareness creation

The project created awareness by establishing demonstration plots, open days, field days, trade fairs, and through local FM radio to educate the public on the importance of high-quality seed potato and improved varieties. Most farmers in Kenya listen to local FM stations broadcasting in the vernacular languages, and this provided an opportunity to create awareness. All of the trained FGs established their own demonstration plots, where they compared farmer seed practices with PS or with certified seed. The groups were also able to demonstrate to other farmers the benefits of quality seed. More than 50% of the farmers trained were women. Demonstration plots showing different varieties, including the newly released ones, fungicide against LB, and fertilizer were also established at strategic sites in the project districts.

Decentralized seed multiplication

Decentralized seed multiplication accelerated the diffusion of released varieties such as 'Kenya Mpya'. Trained secondary seed multipliers were linked to the high-grade seed multipliers such as KARI/Tigoni and Kisima Farm. The secondary seed multipliers were in turn linked to the trained ware farmers. These links allowed the seed multipliers to sell all their seed at farm gate without incurring storage or transport costs.

Creating PPP

The 3G project enhanced ties between the various seed value chain actors and supported services through review meetings, site visits, and regular communication among partners. For example in Kenya, Plant Quarantine Station, a public institution with a TC laboratory, and GTIL, a private farm also with a TC laboratory, were both linked to Kisima Farm to supply minitubers before Kisima built its own aeroponic units. GTIL was also linked to Milwar Farm and Stephen Chege's Farm for field multiplication of the minitubers.

Farmers' perception of quality seed

Farmers were willing to invest in quality seed once they saw its benefits (Kaguongo et al. 2009) (see Figure 8.2). Training helped farmers manage quality seed potato, and ensured continued willingness to buy quality seed potato.

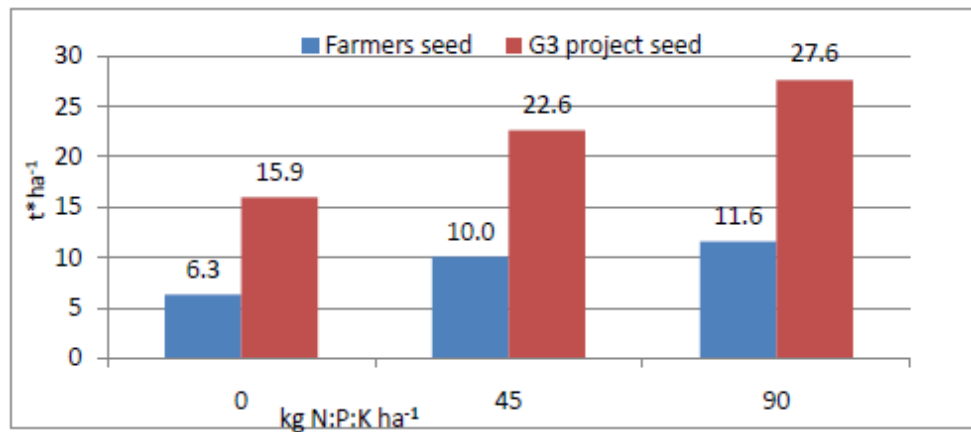


Figure 8.2. Yield of farm-saved seed and 3G project seed under different fertilization rates.

The new dynamics of the seed market

Previously, there was a lack of information on the source and the choice of variety, with most of the farmers having to take whatever variety they could find. With links between actors, the farmers could order the seed even before it was harvested. During the intervention, a list of secondary seed multipliers per district was compiled and given to the high-grade seed multipliers so that they could supply them. Between September 2009 and March 2011, Kisima Farm sold over 400 t of G3 seed potato worth more than \$180,000 (\$400–\$500/t) to the trained farmers.

3.2 AFFORDABILITY OF THE NEW SEED POTATO

The high-grade and secondary seed multipliers sold all their seed at farm gate. The demand for seed increased so fast that farmers who produced G4 seed often sold at a higher price than that of the original 3G seed. The seed multipliers sold their seed to neighbors and to farmers from other districts. Even seed multipliers very close to Kisima Farm sold their seed without a problem.

An economic analysis showed that under existing agronomic practices and prices, using certified seed was less profitable than farmer-saved seed (Ng'ang'a et al. 2003). The large amounts of affordable 4G seed (unleashed by new technology and relaxed regulations) may have made this new, semi-formal seed profitable for ware potato growers. (See Chapter 2 on Ecuadorian potatoes.)

The introduction of small bags encouraged farmers to experiment with quality seed potato in an affordable, low-risk way. About 20,000 farmers were exposed to potato technologies through field days and demonstrations, or by purchasing high-quality seed potato in small packs of 5 or 10 kg. Others heard about the potato technologies through the radio talk shows that were organized on different FM stations—extension officers used local languages to explain about the new technologies and varieties—as well as inviting the farmers to field days. This helped to increase the number of participants in the field days. The prices for a 50-kg bag of seed potatoes ranged from \$20 to \$22 (1,800–2,000 Kenyan shillings). This is more than the price of ware potatoes but much less than the \$30 for certified seed. This

finding supported those of Kaguongo et al. (2009), who observed that farmers were willing to pay more for quality seed.

The partners shared information widely with farmers of both genders. Women were more active than men during the training of FGs.

3.3. SEED QUALITY

3.3.1 *Situation before the intervention*

Seed quality threatening factors

Potato researchers regarded viruses and bacterial wilt (BW) as priorities (Fuglie 2007). More than 70% of farm-saved seed sampled in Kenya had Potato Leaf Roll Virus (PLRV) or Potato Virus Y (PVY) (ibid.). The continued use of this seed led to degeneration via disease build-up.

BW caused by *Ralstonia solanacearum* is spread via seed and soil. The disease causes yield losses of 50–100%; other potato viruses in Kenya can cause yield losses of more than 12% (Muthoni et al. 2010; Kaguongo et al. 2010). The rate of seed degeneration from viruses is related to the abundance of the vector, usually aphids. The viruses reproduce faster and the aphids are more active at high temperatures. Some varieties are also more resistant to viruses.



Viruses carried in seed potato can lower yields
Photo by Jeff Bentley.

Capacities and constrains of farmers to use and maintain quality seed

Only a few farmers knew a trusted seed source, whereas most could not get quality seed at all, in part because of poor roads and long distances to seed sources. Many farmers were unaware of the importance of high-quality seed, which was also expensive.

When farmers' seed has "become tired," farmers look for a new variety, or for clean seed. Farmers can manage their own seed with simple techniques, such as PS (choosing the best plants for seed), NS (roguing), integrated pest management, and improved seed storage. Farmers may also buy seed, especially to get a new variety.

3.3.2 *What changed as a result of the intervention*

Capacity building on virus and BW testing

CIP researchers trained Kenyan national potato researchers in serological diagnostics of latent BW and potato virus infections. This knowledge is now used in surveys of viruses and BW. The scientists were trained to diagnose BW infection in tubers, stems, and soil, since each sample type requires a

different procedure, although all use ELISA principle. The different potato programs were linked to the source of ELISA kits at CIP–Lima. In all the project countries, the national potato programs use CIP virus and BW detection kits (ELISA).

Effect on seed quality and production

The project trained farmers on how to improve farm-saved seed using “select the best” (i.e., PS), NS, and small seed plots. Before the farmer training, CIP and the national programs trained the group facilitators in disease and pest identification and management, PS and NS, DLS, and good agronomic practices; 267 extension officers were trained in Kenya. Over 8,250 smallholders in Kenya (57% women) were trained in seed and ware potato production and in “select the best.” Training by the MoA covered 22 districts.

Effect on capacities to use and maintain quality seed

Before the trainings, farmers in Kenya would keep the small (less than 25 mm), often rejected tubers as seed (Obado 2010; Obado et al. 2010). Others would buy poor-quality tubers from the local market or from their neighbors. There is now a noticeable difference in yield between the farms of the trained farmers and their untrained neighbors.

Differentiation of information

Smallholder farmers improved their seed potato quality through PS by reducing BW and virus infections. This technology can be practiced by all, regardless of gender or education level, and it requires no cash expenses, only wooden pegs (to mark the healthy plants) and some HH labor.

4. Seed producers and seed availability

4.1 THE MODEL

New seed supply model

The project developed a model called 3G, which means that the farmer receives the seed after the third generation. 3G produces large numbers of minitubers through aeroponics, and then yields high-quality seed potato in three field generations, instead of seven. This RMT lowers production costs and reduces the risk of pests or disease. Improved varieties (adapted to local conditions and demands) were produced much faster by involving the private sector. Average yields increased by 20% for more than 15,000 smallholder potato growers (CIP 2011).

Scaling up this model

Kenya produces 1–2 million t of ware potatoes annually (a million-ton harvest requires 165,000 t of seed potatoes), so there is much more potential for private firms to produce more seed.

The semi-formal system produces two types of seed: “clean” and “positively selected.” Clean seed is multiplied on-farm and is not subject to inspection by KEPHIS. It originates from certified or basic seed and is produced by following guidelines laid down in farmer training programs conducted by the MoA and KARI. The growers remove diseased and weak plants. Farmers are technically backstopped by MoA, KARI, and NGOs and were supported by CIP’s PSDA project (Promotion of Private Sector Development in

Agriculture). This seed, which the FAO calls QDS, only requires the development of protocols and legislation. Although Kenya has not yet legalized QDS, other countries (e.g., Tanzania) have already approved this type of seed for trade.

Positively selected seed is produced from farm-saved seeds by farmers who have received training on how to select disease-free plants in the field. These plants then become “mother” plants from which seed for the next season is obtained. This type of seed is not subject to inspection by KEPHIS.

Rapid multiplication techniques

The project supported construction of aeroponics units in the public and private sectors. CIP provided an aeroponics specialist who supervised the installation and gave technical backstopping. CIP trained all the aeroponics technicians and other project team members (including staff from the national potato programs) on how to use the facilities and handle the in-vitro plantlets (hardening, transplanting, nutrient formulation, and maintenance). Aeroponics results in multiplication rates of over 50:1 versus less than 10:1 with conventional soil-based systems. Aeroponics uses less water and energy (Otazu 2010) and makes better use of the vertical space of the greenhouse; root and tuber development is enhanced by the ample space and optimum air-humidity balance.

Market intelligence

In a study before the project, farmers requested training (23%), lower seed prices (25%), and more seed stations (23.5%). Farmers indicated a willingness to pay a premium for certified seeds 1.9 times the price of the farmer seeds; for clean seed 1.7 times the price of farmer seed; and for positively selected seeds 1.4 times the price of farmer seed (Kaguongo et al. 2009).

4.2 BENEFITS FOR THE FARMERS

By using G4 seed, farmers could increase their yields from about 8 t/ha to 16 t/ha. With an average ware potato price of about \$200/t, this leads to an increase in gross receipts of \$1,600/ha. Since G4 seed potato costs \$250–400/t, the profit per hectare is about \$800 (assuming 2 t of seed/ha). A 25% investment risk factor was incorporated into the calculation of the potential profits, based on the assumption that 60% of the 4G seed produced will be used as seed by the smallholder farmers and 40% sold as ware. Farmers should be able to earn \$325 more per hectare than if they use their own seed. This converts to an additional 180,000 t of potatoes and an annual benefit of \$7.3 million for farmers. “Save the best” seed yielded on average 37% more than the previous farmer-saved seed. Of the 18,000 farmers trained in the project, 30–40%, adopted the practice. This should lead to an increase of 5,184 t/year of potatoes and extra profits of \$777,600.

4.3 QUALITY ASSURANCE AND REGULATION

Staff of the national research program was trained in advanced disease diagnostic and management techniques. The seed multipliers had the option of registering with KEPHIS as seed merchants (for a fee of about \$750) where they could go for certification.

Farmers trained by the project attributed their increased yields to the use of well-sprouted quality seed of improved varieties, good agronomic practices, and control of LB and BW. Kisima Farm recorded yields as high as 70 t/ha, which is exceptional; more representative multipliers still produced a respectable 30–40 t/ha.

5. Regulation and policy affecting farmers' use of quality seed

5.1 POLICIES AND SEED REGULATION

Effectiveness of the policies

The seed and plant variety legislation was not supportive of the informal seed sector. The state monopoly in seed inspection and certification hampered the production of certified seeds, and some seed growers lost their crops due to late inspection by an overstretched, under-resourced seed inspection service. The stifling regulatory system slowed the dissemination of improved varieties due to the long periods of testing required before a variety could be approved and released. High prices in the formal system discouraged farmers from buying these seeds (Rohrbach and Howard 2003).

Relevant policy changes

During the project there was a recognition of the need to revise the legal framework. The lack of a stakeholders' forum or an institutional structure for advocacy contributed to the slow revision of seed policies and regulation (Kaguongo et al. 2010). Seed certification is carried out only by KEPHIS, but a bill currently before parliament will allow for private seed inspectors.

5.2 SEED HEALTH

The DVMs usually plant certified seed to produce clean seed that they sell to farmers. Most multipliers are able to sell their seed, even if it is not certified, because they have earned the trust of their customers (who can observe the crop in the field). For the past 30 years Kenya has not imported or exported certified seed potatoes. Opening the border has led to imports of potato seed from other countries.

Quality Declared Planting Materials

QDS is not recognized under Kenyan law, and its trade is illegal; however, there are recent attempts to encourage the authorities to recognize this type of seed.

6. Seed multiplication tools and techniques

The project used two approaches to address the bottlenecks of the seed system: (1) selecting farmers to produce clean seed to sell to other growers, and (2) training potato farmers to select and maintain healthy potatoes on their farms.

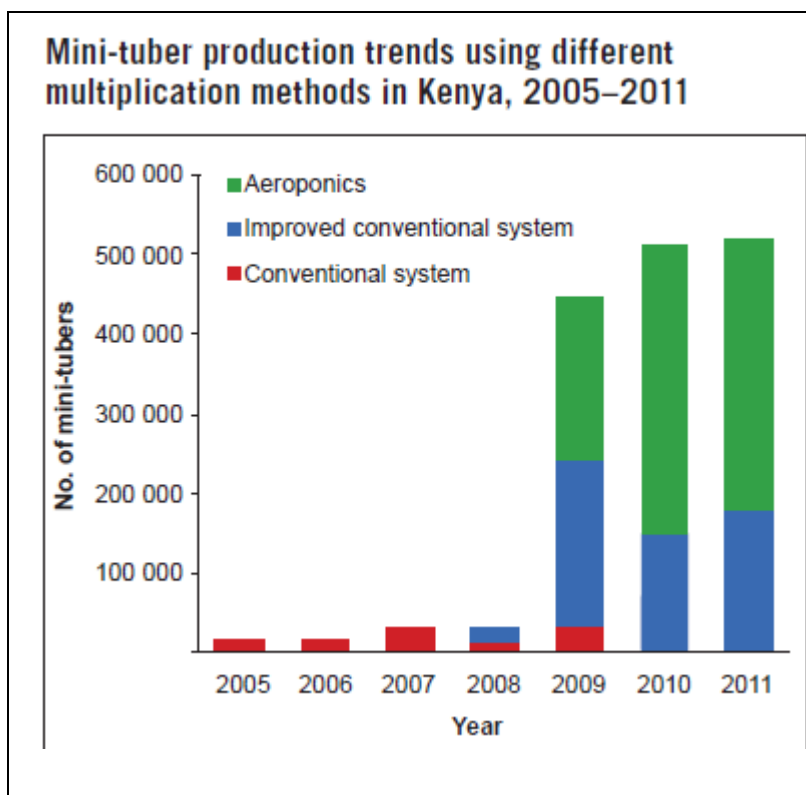
Seed potato is bulky and transport costs are high, so multiplication should take place near the farm. From 2008 to 2011, more than 18,000 ware potato farmers from all the major potato-producing areas were trained to use PS. Training was facilitated mainly by MoA extension agents and, in some cases, by farmer trainers who received intensive classroom and field training in field multiplication, disease and

pest identification and management, farm hygiene, seed production, postharvest, and PS. The trainers were given a set of detailed books on seed potato production and illustrated books for identifying pests and diseases.

Select the best (PS) helped trained farmers improve the quality of their own-saved seed potatoes by reducing the levels of BW and viruses. Results from 25 FGs demonstrated that positive seed selection improves seed quality and increases productivity by 10–40%.

For many years, Kenya relied entirely on the TC facility at KARI/Tigoni. This limited the annual output of in-vitro plantlets. Between 2008 and 2011, the capacity increased with a new TC facility built at ADC/Molo in 2009, and by upgrading the TC unit at KARI/Tigoni in 2010. In 2008, a private firm, GTIL, began producing in-vitro plantlets and minitubers under a PPP supported by USAID and the Kenya-Germany Promotion of Private Sector Development in Agriculture (GIZ/PSDA) program. CIP also maintains a TC laboratory at the KEPHIS station in Muguga.

In 2008, the project introduced aeroponics for minituber production and helped build nine aeroponics units in Kenya and an improved conventional system at the Muguga Station. The nine units had a capacity of about 26,000 plantlets. Seven of the nine units were built by private firms on a 50:50 cost-sharing basis; the other two at the public institutions were funded by the project. The private units are owned by GTIL (three units), Kisima Farm (two units), and one unit each at Kagia Farm and Suera Farm. By June 2011, at the close of the project, 1,205,596 minitubers were produced. The project proved that aeroponics can produce high-quality seed potato more quickly.



The two aeroponics units built at public institutions are no longer functioning, partly because of the lack of a reliable power system. The units need electricity, and the frequent power failures without backup power made it impossible for the crops to survive. Government procurement procedures also delayed the timely acquisition of nutrients and other supplies, and minor repairs could not be done on

time, leading to major losses and damages. There was also no full-time technical expert to manage the units; the staff who was supported by the project could not continue after the project ended.

Of the seven units built by private firms, five are still functioning (Kisima Farm with two units and GTIL with three). Kisima Farm has even increased the size of its units.

Two aeroponics units built by private progressive farmers have since been abandoned, due to the high costs of production and the long time needed to break even. Aeroponics are only profitable if the farmer has land for further field multiplication to recover costs and make a profit by selling 3G seed. These farms also lacked technical experts and backstopping to manage the units after the project ended. There was no demand for the expensive minitubers because of their cost. To make a profit one would have to sell the minitubers for \$0.25, which is too much for most farmers.

Aeroponics is also a risky technology and cannot be used everywhere. Failures can result from problems with electricity, water quality, weather, greenhouses, the plant material, and management. About 60% of the 3G seed was used to produce more seed.

CIP convinced public and private farms to invest in aeroponics. Kisima Farm and GTIL collaborated with CIP to obtain partial funding from USAID for their aeroponics units, and CIP provided technical backstopping. Kisima also collaborated with GIZ-PSDA and FIPS-Africa, to create awareness and to distribute some of their certified seed. When Kisima was first becoming established, it was in a partnership with KARI and used KARI's seed merchant certificate to produce certified seeds. Kisima Farm multiplied KARI's latest variety releases (2010) of 'Kenya Mpya', 'Kenya Sherekea', and 'Purple Gold'. CIP's germplasm for the region is multiplied by GTIL, which currently exports most of its minitubers; Kisima also exports some minitubers. The private sector is willing to invest in minitubers and quality seed potato business because of the available market.

7. Lessons

Aeroponics

Involving the private sector can overcome the supply bottleneck for quality seed, especially when combined with RMTs, better integration of NARS and extension systems into the value chain, and farmer training in seed management and storage

Willingness of the private sector to invest in seed potato production

The private sector is willing to invest in seed potato because of the business opportunities (which still need to be streamlined). The system needs a strong PPP for producing starter seed and a decentralized seed system, supported by extension services (such as the MoA) to train farmers and seed multipliers.

Willingness of smallholder farmers to buy quality seed potato

Farmers are willing to invest in quality seed once they see the benefits; however, farmers need training to use and manage quality seed potato. Training in business skills helps to ensure continued willingness to buy quality seed potato.

Creating awareness

Smallholder farmers have more opportunities when in groups or associations for acquiring inputs, credits, and for selling potatoes. Most of the farmers' soils have been degraded, but fertilizers can increase potato yields. Field days and demonstrations have a greater impact than workshops and centralized meetings. Media (e.g., radio talk shows) can have a wider impact in sensitizing the communities about potato technologies.

Assumption on seed cost

It was expected that the decentralized multiplication of the quality seed will bring down the cost of seed, yet this was not the case. In a follow-up telephone survey, the multipliers reported selling the 4G seed at even higher prices than what they paid for the 3G seed. This suggests that there was a vast, unmet demand for seed, which was possibly increasing.

References cited

- Atieno E. 2015. Tackling the food price crisis in Eastern and Central Africa with the humble potato: Enhanced productivity and uptake through the "3G" revolution." Paper presented at the RTB Seed Workshop held in Gainesville, Florida, 21–23 September 2015.
- Ayieko M, Tschirley D. 2006. Enhancing access and utilization of improved seed for food security in Kenya. Working paper No. 27/2006. Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya.
- [ECAPAPA] Eastern and Central Africa Programme for Agricultural Policy Analysis. 2005 Managing Conflicts Over Pasture and Water Resources in Semi-Arid Areas: Beyond Misleading Myths and Ethnic Stereotypes Policy Brief No. 8.
- Fuglie KO. 2007. Priorities for potato research in developing countries: Results of a survey. *American Journal of Potato Research* 84(5):353–365.
- Gildemacher P, Kaguongo W, Ortiz O, Tesfaye A, Woldegiorgis G, Wagoire W, Kakuhenzire R, Kinyae P, Nyongesa M, Struik P, Leeuwis C. 2009. Improving potato production in Kenya, Uganda and Ethiopia: A system diagnosis. *Potato Research* 52(2):173–205.
- Kabira JN, Wakahihu M, Wagoire W, Gildemacher P, Lemaga B. 2006. Guidelines for production of healthy seed potatoes in East and Central Africa. Nairobi: Kenya Agricultural Research Institute. 28 pp.
- Kaguongo WP, Gildemacher P, Demo P, Wagoire W, Kinyae P, Andrade J, Forbes G, Fuglie K, Thiele G. 2008. Farmer practices and adoption of improved potato varieties in Kenya and Uganda. *Social Sciences Working Paper 2008-5*. Lima: CIP. 85 pp.
- Kaguongo WP, Ng'ang'a NM, Muthoka N, Muthami F, Maingi G. 2010. Seed potato subsector master plan for Kenya (2009–2014). Seed potato study sponsored by GTZ-PSDA, USAID, CIP and Government of Kenya. Nairobi: Ministry of Agriculture.

- Muthoni J, Mbiyu MW, Nyamongo DO. 2010. A review of potato seed systems and germplasm conservation in Kenya. *Journal of Agricultural and Food Information* 11:157–167.
- Obado J. 2010. Tackling the food price crisis in Eastern and Central Africa with the humble potato: Enhanced productivity and uptake through the “3G” revolution. Nairobi: CIP.
- Olanya OM, Adipala E, Hakiza JJ, Kedera C, Ojiambo PS, Mukalazi JM, Forbes G, Nelson R. 2001. Epidemiology and population dynamics of *Phytophthora infestans* in sub-Saharan Africa: Progress and constraints. *African Crop Science Journal* 9:185–193.
- Otazu V. 2010. Manual on Quality Seed Potato Production Using Aeroponics. Lima: CIP. 44 pp.
- Rohrbach DD, Minde IJ, Howard J. 2003. Looking beyond national boundaries: Regional harmonization of seed policies, laws and regulations. *Food Policy* 28(4):317–333.

CHAPTER 9

Research reawakens in Nicaragua

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Abstract

From 2005 to 2007, CIAT's Cassava Program and CLAYUCA (Consortio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca), a nonprofit based in Colombia, had a project with Nicaragua's national agricultural research agency, INTA (Instituto Nicaragüense de Tecnología Agropecuaria), to introduce and test new cassava varieties. The change of government in Nicaragua in 2007 was accompanied by new policies and massive staff turnovers that left the project inoperable. Years later, private companies became interested in some of the varieties that the project had introduced. These varieties had survived (e.g., in the fields of farmers who had collaborated with the varietal trials, or on INTA stations). The food-manufacturing companies began rearing cassava as planting material and distributing cuttings to farmers who were eager to sell cassava roots to the companies. The farmers were happy to grow the new varieties. Although the presidency of Nicaragua has not changed since 2007, the government agency INTA is once again interested in testing and promoting at least some of the project's cassava varieties, in part to satisfy the burgeoning needs of snack foods manufacturers. INTA, processing companies, farmer organizations, donor-funded projects, and CLAYUCA are once again discussing how to make those varieties part of a new national seed system for cassava.

Rationale

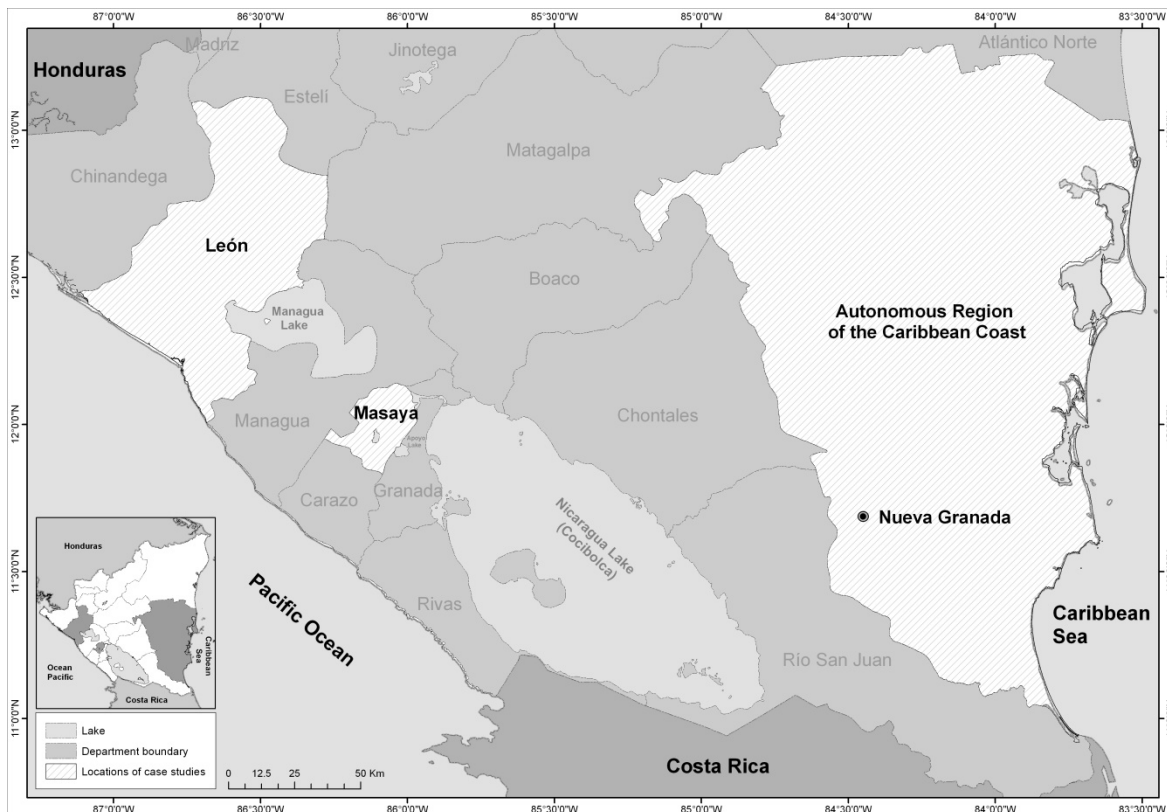
Farmers have been growing cassava for a very long time in Nicaragua, mainly as a food security crop, and selling some excess production for consumers to eat fresh (e.g., boiled). Farmers were used to producing their own stakes (planting material). Recent developments include greater demand for cassava, for domestic consumers, and for export. Processors are now buying larger amounts of cassava to, for example, process as snack foods (chips). Manufacturers require specific varieties.

1. The intervention

Although this case started years ago, it is still a work in progress. Around 10 years ago, CLAYUCA and CIAT, upon request by INTA, started a pilot project to introduce, evaluate, and select improved cassava germplasm with high yield potential and good adaptation to the soil and climate of Nicaragua. At that time, INTA had just become a member of CLAYUCA, and part of the work plan was to give Nicaragua easier access to the new cassava varieties available at CIAT.

CLAYUCA, then operating as an informal consortium attached to the Cassava Program of CIAT, received a selected group of varieties (as in-vitro plants) and developed and implemented a pilot strategy, with INTA, to conduct field trials with these varieties in Nicaragua. (In 2012, CLAYUCA started to work as a small, independent nonprofit corporation, although maintaining the collaborative relationship with CIAT). CLAYUCA trained INTA staff, both at CIAT and in Nicaragua, and improved INTA's TC laboratories, screenhouses, and greenhouses. CIAT and CLAYUCA staff also participated in field activities in Nicaragua. INTA's support was crucial, and included investments for upgrading the installations and designating members of staff with responsibilities to conduct the field trials.

The pilot project lasted for two years and had excellent results. The group of introduced, elite cassava varieties was rapidly multiplied in INTA's TC laboratory. Many in-vitro plants from each variety were hardened in the screenhouses and greenhouses. During the first year, field trials were established at four locations.



INTA staff, and some FGs, participated in the field activities. At the end of the first growing cycle, a preliminary group of the varieties was selected as promising and recommended for further evaluations. The selected varieties obtained high yields, and a first group of introduced varieties was selected for its quality and likely acceptance in different markets (fresh produce, animal feed, industry). CIAT, CLAYUCA, and INTA were pleased with the project results, and everything seemed to be working toward a great,

lasting impact. Public and private institutions and FGs were starting to have a facilitated access to new, improved cassava varieties that could contribute to increased income, jobs, and food security.

Then in 2007, Daniel Ortega was re-elected president of Nicaragua, having previously been president from 1985 to 1990. As is normal in Central America, all of the top technical people in the government, including INTA, were replaced. As a consequence, momentum and intensity of the work with cassava were lost. The field evaluation trials were suspended, and INTA cut its relationship with CLAYUCA.

By 2014, however, INTA has a renewed interest in working with cassava. There are regional initiatives for promoting agricultural development, including cassava, with financial support from the European Union (PRIICA project: Programa Regional de Investigación e Innovación por Cadenas de Valor Agrícola) in which INTA participates (Sanclémente 2013). There are now four new private agro-industrial projects based on cassava that are demanding improved varieties. On top of this, RTB, through CIAT, IITA, CIP, CIRAD, and collaborators, including CLAYUCA, is working on initiatives such as improved seed systems for root and tuber crops (INTA 2013a; 2013b; Ministerio de Fomento, Industria y Comercio 2012).

At the time of this case study, the actors of the cassava chain were once again talking about establishing a cassava seed system in the country. While doing this case study, CLAYUCA was able to interact with all the stakeholders and visit their projects, cassava fields, and processing factories. The initial framework, defined and agreed by the cassava seed system stakeholders in Nicaragua, has a good potential to develop, evolve, and function.

The new national cassava seed system in Nicaragua includes the following: (1) INTA introduces elite, improved cassava varieties from international research centers such as CIAT (Colombia), INIVIT (El Instituto de Investigaciones de Viandas Tropicales, Cuba), Embrapa (Brazilian Agricultural Research Corporation), and others; (2) INTA evaluates these varieties in Nicaragua, in field trials at experimental stations, farmers' fields, and with private companies; (3) INTA, with farmers, private companies, and universities, establishes cassava seed banks in selected regions; and (4) INTA, farmers groups, and private companies distribute cassava planting material of elite, improved varieties to all the actors of the cassava chain, with emphasis on agro-industry.

This system involves three private companies and three farmers' organizations, coordinated by INTA. This national initiative was pushed by the PRIICA project, a regional initiative covering four crops including cassava. The initial target is to have the cassava seed banks established in the fields of these



Researcher with new cassava varieties. New resistant varieties can be distributed once to farmers, who then reproduce them.
Photo by Bernardo Ospina.

six stakeholders between September 2014 and June 2015. Each cassava seed bank will cover at least 1 ha. INTA will provide planting material of elite varieties.

Theory of change

Cassava is a strategic crop in Nicaragua, largely in the hands of smallholder families, who grow it by hand, with low yields. Most of the crop is grown to ensure that the farm HH has something to eat. Any surplus is sold, with little value added. Most farmers prefer to plant cassava varieties that they already know, such as the variety 'Algodón', which is well accepted in the market and by the industries that process for export.

The planting material is usually taken from the previous crop. There have been few efforts by the formal sector to introduce improved varieties, or to improve the local ones. There is a high demand for high-quality cassava planting material of improved varieties, and farmers recognize its importance to increase the productivity of the crop.

INTA evaluations of cassava varieties in the last 10 years have allowed some FGs to start using new cassava germplasm, with high acceptance. But these efforts have been intermittent and limited to some of the main cassava-growing regions. Agro-industry has increased the market options for the farmers, and processors' demands for specific varieties are once again sparking farmers' interest in new varieties. Between 2007 and 2010, two of these private companies began exporting cassava to the U.S., including some of the varieties previously introduced by INTA and CLAYUCA.

Scaling up

The intervention has been agreed by various actors of the cassava chain, and is starting with an excellent group of elite varieties; adapted to different ecosystems in Nicaragua; and accepted by farmers, processors, and consumers.

The three private companies are farming rather large areas by themselves (200–400 ha), and these areas will soon be planted with improved varieties. The four most important projects are Opportunity International, Empacadora Daysa, Empacadora Vargas, and Tecnoagro. A fifth one, Nica Starch, cancelled operations after the case study was implemented. Each of these projects has many farmers who supply cassava roots to the factories, and these farmers will be eager to plant the cassava varieties that are demanded by the companies.

Demand for new cassava varieties is expected to grow, as the intervention starts to produce results. More good quality planting material of improved varieties will be available, and more farmers will be interested in adopting them.

Framework: Cassava in Nicaragua

Stakeholder	Availability / supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Policymakers					After a hiatus of several years, policy again favored new cassava varieties	Will need to address health & quality in future
National research					INTA is once again working with cassava varieties	Will need surveillance of cassava health
International research					New varieties originally provided by CIAT via CLAYUCA	
Traders (local markets)	Seed of most old varieties produced by farmers					
Private seed sector		This role is filled by processors				
Farmer organizations		Farmer organizations not well equipped to produce and sell seed				
NGOs						
Private sector processors	Producing some seed of new varieties	Distributing some seed to selected farmers	Seed is easy to multiply	Demanding more cassava roots	Processors demand new varieties	No doubt will have quality standards
Seed users	They can produce their own seed, once they get the variety	Often obtained directly from processors	Not an issue	Farmers want to sell to processors		

2. General context

Type of farming systems

The cassava farming system in Nicaragua is based on many smallholders, scattered in regions far from the main cities, with poor roads and weak ties to urban markets. Although most cassava-growing regions have good soil and climate for the crop, yields are rather low, and farmers use few modern inputs. Most farmers use local varieties. The cassava crop has emerging problems with soil erosion and soil fertility. Farmers complain of the lack of technical assistance and training. Few farmers treat the planting material with fungicides and zinc so that they store better over the 1–2 months between harvest and planting. Fields are plowed by oxen, although private companies are using tractors.

Market importance of cassava for the farmers

Cassava farmers in Nicaragua provide raw material to medium and large factories, which process it into paraffin-coated cassava, fried chips, and frozen cassava chips. Farmers often receive low prices because they need to sell the harvest quickly. Poor access roads increase transportation costs.

The cassava area in Nicaragua is around 23,000 ha, with an average yield of around 14 t/ha, of which only 2.5 % is exported and 2.5% is processed by national industry. During the past five years, large, private agro-industrial projects have started to establish cassava fields and factories.

General characteristics of the cassava seed sector

There is no formal cassava seed sector in Nicaragua. Some FGs, in a few regions, have already begun to grow some of the varieties introduced by INTA, with good results. But there is also a lot of confusion about the correct names of these varieties (Figure 9.1).

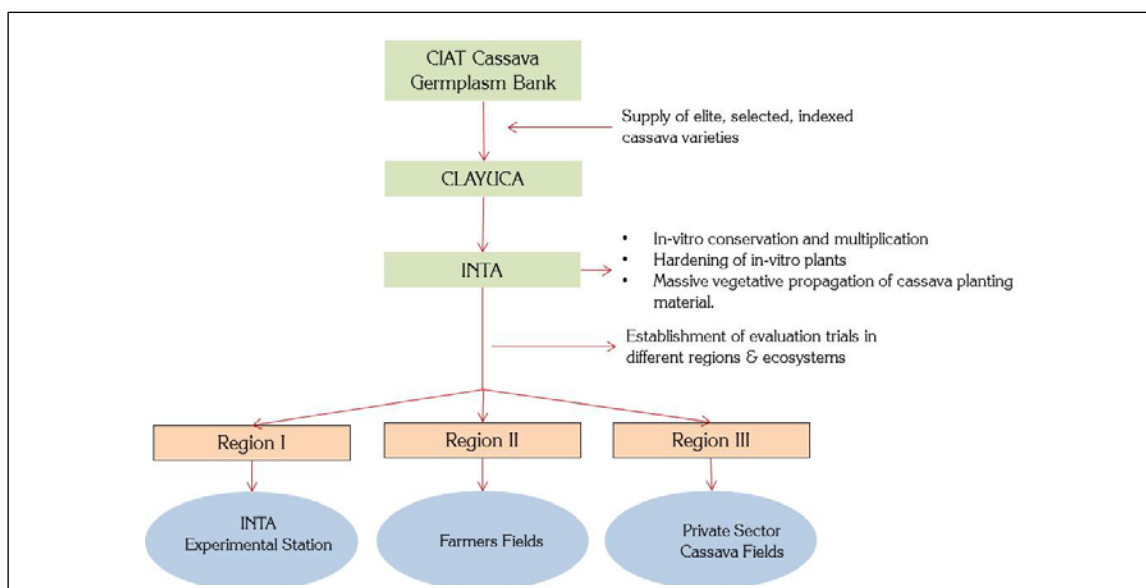


Figure 9.1. Preliminary diagram of a national system for cassava (for varieties that have already been released).

One farmer group tried to start a business based on selling planting materials of improved cassava varieties. Other than this, no farmer, group, or company has tried to sell cassava planting materials.

Trends, developments, ongoing change

Private investors have been attracted by the price of good land, the climate, abundant work force, and stable policy environment. Six large projects are operating in the country and will soon be responsible for almost one-third of the cassava grown in Nicaragua. This trend will increase the demand for cassava seed. The PRIICA project has allowed INTA to coordinate with various potential users for the seed system, including FGs and private cassava projects.

3. Seed users

3.1. SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 Before the intervention

The cassava farmers in Nicaragua collect and select planting material at harvest. They tend to select the healthiest, best-looking, and most productive plants for cutting stakes. Cassava is usually planted from May to December, during the rainy season. The only way to get planting material at the beginning of the rainy season is to use some of the cassava plants that were planted during the previous rainy season.

One farmers' group had some experience with the two-node propagation method, to increase the volumes of planting material. Women are not very active acquiring or using seed. In Nicaragua, women participate in cassava growing mainly at harvest and in the processing factories.

Few cassava farmers currently have easy access to other sources of cassava planting material, other than their own-saved seed. These farmers are usually located close to a cassava agro-industrial company, and want the material to meet the demands of the company. Depending on the market, farmers grow varieties that give good yields, with good flavor, good cooking quality, and pulp color.

A 2013 survey of 120 farmers in one of the most important cassava-growing regions, Nueva Guinea, indicated that 65% of the farmers were getting the planting material from their own plots; 18% were buying planting material from local vendors, generally sold as a mix of varieties, with no identification of the origin or name of the variety (Sanclemente 2013). Most of this production will be rejected by the processing companies and has to be consumed locally. In the same survey, 9% of the farmers indicated that they were getting planting material through institutions, projects, and programs.

Farmer information on availability

The work by INTA from 2004 to 2014 was done at experimental stations, but also with many FGs and communities. This gave farmers a voice in selecting the varieties, incorporating their opinions about yields, cooking properties, market acceptance, and other characteristics. Few farmers use these improved varieties because national institutions did not disseminate them. The few farmers who use these varieties now are the ones who are linked to the agro-industrial projects that maintain nurseries of these varieties to provide planting material to farmers. In general, farmers know about these new varieties but do not know where to obtain them, or how to maintain the quality.



Cassava is reproduced from cuttings of the stem
Photo by Jeff Bentley

Differentiation of information

About 60% of the farmers have not received any training in cassava technologies. Women's groups, with little participation in cassava growing, and indigenous groups, usually located in the more distant areas, also tend to be excluded from training and from sources of new varieties.

3.1.2 What changed as a result of the intervention

Some new varieties were introduced into the country about 2004 (Guido 2005; Vega and Aburto 2006). INTA tested them in trials with farmers, until about 2007. Some farmers who were involved in the trials continued to multiply the new cassava. Later, private agro-industrial companies became interested in some of these varieties to use in food manufacturing. The companies are growing some varieties and making them available to farmers who supply the manufacturers.

3.2. AFFORDABILITY OF THE NEW SEED

Farmers will only need a few stakes to acquire the new varieties. In most of the evaluation trials the new varieties outperformed the local ones. These new varieties are meeting high demand by the processors, and farmers will want to start using these new varieties. Farmers will still try to grow the varieties that they eat at home. Most of the private cassava companies have the land, irrigation, technical personnel, and capital needed to disseminate the new varieties to the farmers linked to the companies.

The only experience of a farmers' group investing resources (land, capital, labor), to sell cassava planting material is the group known as Nicarahuac. According to them, it was difficult to make the business profitable.

3.3 SEED QUALITY

In this case, the concept of seed is closely linked to the new varieties. Although seed quality usually implies health and purity, in this case it means yield, size of the roots, percentages of roots of different sizes, dry matter content, starch content, cooking quality, and color of the pulp.

Farmers' needs for planting material are easily solved at the local level; farmers only need outside seed in order to obtain new varieties.

INTA and collaborators will promote mass production and distribution of good quality seed of these improved varieties. The system will use TC to clean local varieties that have been in the hands of farmers for years and that are well accepted by the market. These varieties will be included in the seed system.

3.3.1 Before the intervention

For the most common local varieties, such as 'Algodón', 'Linda', 'Señorita', 'Brasileña', and 'Valencia', disease is the biggest threat. These varieties have been planted for many years, and they have degenerated. Pests and diseases of cassava in Nicaragua include super-elongation, thrips, mites, and cuero de sapo (frog skin—causal agent unknown). These varieties have never been cleaned with TC. The storage period for cassava stems, from the end of the rainy season to the next planting season, also causes some damage to the planting material.

For improved varieties, the main pests are super-elongation and thrips, to which some introduced varieties are already showing susceptibility. Some of the promising varieties introduced by INTA were lost, and some were still in the hands of scattered FGs.



Damage by cassava mites.
Photo by Jeff Bentley

3.3.2 *What changed as a result of the intervention*

It is still too early to determine any changes as a result of the intervention. The potential impact is related to the:

Cassava varieties with higher yields, well adapted to the main ecosystems in the country and accepted by farmers and markets.

International institutions are supporting the efforts led by INTA to develop the cassava sector.

New national policy reinstates cassava as a government priority. Some of the municipalities of Nicaragua (e.g., in Nueva Guinea) are establishing regional consortia, in which FGs and companies are joining efforts to improve cassava yields, with seed production for example.

Agro-industry is creating a strong demand for high-quality seed of improved varieties in large volumes that will require an organized, national cassava seed system.

4. Seed producers and seed availability

4.1. THE MODEL

Each one of the six large companies in Nicaragua has started to ensure a constant supply of planting material, for themselves and for their many farmer-suppliers. During the next two years the companies will allocate land, capital, labor, and technical staff to collaborate with INTA to produce and disseminate planting material to many cassava farmers. This model assumes that there will be easy access to the improved varieties and a solid partnership with INTA and with FGs. The one farmers' cooperative that has been producing and selling cassava seed has had access to some of the improved varieties. In spite of poor business and inconsistent demand, this cooperative has also agreed to be a partner in the intervention.

Scaling up

If the companies buy more cassava, farmers will want more seed of the new varieties. Smallholders in Nicaragua cannot afford to leave their fields unharvested for more than 8–10 months. To get good seed of new varieties, some cassava fields will have to be left unharvested over the dry season to be able to cut fresh stakes when the rains start. This is easier for the private companies, with their abundant land, than for the farmers' cooperative.

Rapid multiplication techniques

Only INTA uses TC for rapid multiplication of cassava varieties. And although the companies and the farmers' cooperative will not use TC, they will use the two-node multiplication method. So far, they have no experience with this technique, but they will be trained by INTA as part of the intervention.

Market intelligence

The project did not conduct studies to gauge the demand of its varieties. Yet years after the first varietal trials were done, the new private companies found that some of those new varieties were

useful for processing. It is unclear whether this was because of market intelligence or luck; but INTA, the six companies, and several farmers' organizations became interested in working together.

4.2. BENEFITS FOR THE FARMERS

Centers like CIAT and IITA have been working for decades with donor support to create genebanks with thousands of accessions. However, farmers rely on old varieties, which have been passed from farmer to farmer for many years, with limited access to new cassava varieties.

Work like INTA's gives smallholders access to more productive varieties, and to improved seed systems. The benefits are higher yields, better quality cassava roots, improved access to markets, higher incomes, more jobs, and more secure food.

One potential disadvantage is that some of the new varieties could be susceptible to pests and diseases. This could be minimized if the varieties passed through a selection and adaptation process, controlled by INTA, before being released to farmers. The improved varieties in Nicaragua have been around for some years now, and reliable data support their adaptability and potential high yields.

4.3 QUALITY ASSURANCE AND REGULATION

Nicaragua has formal mechanisms to ensure the quality of the genetic material that is distributed to farmers; these regulations are relatively new for cassava. INTA has fulfilled all the requirements to obtain authorization to liberate the first group of improved varieties, based on the first varietal trials from 10 years ago. So, the origin of the genetic material and its quality is guaranteed. As these varieties become widely planted, it will be impossible to control farmer-to-farmer transfer of seed. If a variety gets infected by a disease, and the local institution is not able to detect it in time, the problem could spread rapidly. Quality will be relatively easy to control in the companies, but more difficult with FGs.

Nicaraguan regulations stipulate that any organization, public or private, or even a farmers' group that wants to become a specialized producer and distributor of cassava planting material, must meet some requirements that have been defined by the MoA.

INTA, the companies, and FGs experienced the benefits of the improved varieties. But this new seed system is just starting, and assumes more interaction between all the stakeholders.

Owing to the severe drought in 2015, it was only possible to plant in one site that had irrigation.

5. Regulation and policy affecting farmers' use of quality seed

5.1. GENERAL POLICIES AND SEED REGULATION

Nicaragua has a policy framework that deals with seeds (introduction, release, and plant health), supervised by various institutions:

MIFIC (Ministerio de Fomento, Industria y Comercio—Ministry of Development, Industry and Trade) establishes regulations for introducing of genetic materials into the country.

MAG (Ministerio de Agricultura y Ganadería—Ministry of Agriculture and Livestock) is responsible for implementing the regulations.

IPSA (Instituto de Protección y Sanidad Agropecuaria—Institute of Agricultural and Livestock Health and Protection) writes the regulations and requirements.

CNC (Comisión Nacional de Semillas—National Seed Commission) receives and evaluates requests for authorization to release varieties in Nicaragua. The CNC includes representatives from the public and private sector, and universities.

INTA obtained authorization to release six varieties, as adapted and accepted in Nicaragua. This happened only in 2014, after more than a decade of work, which is an extremely long time for a project.

Policy changes

The intervention is just starting, but it will bring some changes in policy because current regulations may not be sufficient to cover large-scale private involvement. The regulations will have to be adapted to the conditions of the FGs.

All the institutions that are participating in this intervention expect that some of the main beneficiaries will be the poorest farmers and women, although the main benefits for women probably will come from increased production and jobs in the processing plants.

5.2. SEED HEALTH AND QUALITY

The standards that are appropriate for the intervention will have to emphasize plant health. The intervention is based on the six cassava varieties that have been evaluated and selected by INTA, which came originally from Colombia, which has different health problems. During the first 10 years of field evaluation in Nicaragua, the varieties have shown some susceptibility to diseases such as *Cercospora*, root rot, and frogskin, and to some pests such as mites, thrips, and termites.

These standards are appropriate and must be taken into account at the local, national, and regional levels, because there is some traffic of cassava planting material to neighboring countries, especially by farmers who cross the borders to work in other countries and bring back seed to Nicaragua. This is probably how the frogskin disease arrived in Nicaragua. INTA needs to monitor the performance of the varieties, and stop spreading them if any of them results in high susceptibility to any pest and diseases.

6. Seed multiplication tools and techniques

What works best?

For FGs, the best method is the RMT, based on the two-node stakes. CLAYUCA has implemented this farmer-friendly method in various countries. Farmers rapidly learn the technique and obtain good quality planting material.

For specialized seed producers, such as the companies, the best model could be a centralized approach, using in-vitro multiplication on their own farm, with facilities for hardening and using the two-node RMT. This approach can produce massive amounts of planting material that can be distributed to the farmers who sell cassava roots to the factories. This method will require some investment in

facilities and in specialized personnel, however. The companies could avoid in-vitro multiplication if INTA or another public institution could do it instead. The intervention does not expect private companies to establish TC facilities in the short or medium term.

The best way to identify each type of user is to involve them, from the beginning, in defining the scope, strategy, activities, and responsibilities. INTA is starting the intervention with a sound approach, promoting an innovative scheme called the “Voluntary Association Agreement of the Local Consortium for Research and Technical Innovation of the Cassava Chain in Nicaragua” (CLITA). This approach is a spin-off of the activities proposed by the PRIICA project. The main actors of a CLITA are the FGs, INTA, the companies, universities, and other institutions.

The CLITA for cassava was signed on August 19, 2014, with the participation of:

Public Sector: MAG, INTA, MEFCCA

Private Sector: Opportunity International

Farmer Groups: COOPMULCAB-RL, COAGRO-RL, COASMA-RL, NICARAHUAC, Cooperativa Agro-Industrial El Capulín

University: UCA.

If this approach proves to be successful, it could become an option that can be replicated in other areas of the country.

Capacity development is a key element of the intervention. INTA has technical personnel trained in TC techniques and RMT such as the two-node technique. INTA has two TC laboratories that have been improved; another is under construction. Additionally, INTA has the National Centre for Agricultural and Biotechnology Research, in which they conduct basic research in genetic improvement of some crops. This institute has a molecular biology laboratory.

Another partner institution, the Universidad Nacional Agraria (UNA), also has a TC laboratory. It has developed a technology known as economic bioreactors for temporary immersion, with which it is obtaining high multiplication rates with some crops, including cassava. INTA and UNA currently have only 12 molecular markers, and are interested in acquiring more to conduct more precise indexing work with cassava genotypes.

Scaling up

There are good links between public sector, companies, and FGs, and the strategies that are under implementation have the potential to enhance this integration. The private sector is eager to participate.

INTA has not yet used the wide range of technologies that are now available for improving the conventional propagation methods (e.g., somatic embryogenesis). There are interesting models available, such as the “Centers for Accelerated Reproduction of Seeds,” developed by INIVIT in Cuba, that could be used by INTA. These new biotechnology-based approaches could increase INTA’s multiplication ratios.

7. Lessons

It is too soon to decide whether the project's assumptions and expectations were realistic. On the basis of the previous work, one could argue that:

Many farmers are interested in receiving clean, high-quality planting material of new, improved varieties. There are markets demanding the cassava roots of these varieties, and this is a great driver of the increasing demand by farmers.

By planting these new varieties, farmers will get higher yields, better cassava roots, and higher prices. Farm incomes will increase, as will the quality and the volume of the seed.

Agricultural projects operate in a political environment. Central America is not the only region where (following elections) the new president and the new ruling party introduce changes in the staff of entire ministries, sometimes without allowing an overlap between departing and incoming staff. This, coupled with policy changes, may mean that even sound projects may suddenly find themselves with no counterpart staff, and with little interest from the minister in seeing that the project lives on. At this stage, high-level lobbying of the new government is crucial. As we saw in this chapter, sometimes government can lose interest in an initiative, and then several years later see its merits, especially if new economic opportunities (such as cassava processing) give the project a renewed relevance.

References cited

- Guido A. 2005. Evaluación preliminar de 12 genotipos de yuca para consumo humano e industrial en el Pacífico Sur de Nicaragua. Managua: INTA.
- [INTA]. 2013a. Guía Metodológica: Organización de Bancos Comunitarios de Semillas. Managua: INTA.
- INTA. 2013b. Guía Tecnológica de la Yuca. Octubre 2013. Managua: INTA.
- Ministerio de Fomento, Industria y Comercio 2012. Análisis de Encadenamientos Productivos para la Generación de Valor Agregado en Nueve Cadenas Agroalimentarias Ubicadas en las Zonas de Mayor Potencial Productivo de Nicaragua. Managua: Ministerio de Fomento, Industria y Comercio.
- Sanclemente OF. 2013. Línea de Base. Cadena de la Yuca, del Consorcio Local de Innovación tecnológica en el Municipio de Nueva Guinea, Nicaragua. Comisión de Seguimiento IICA-INTA.
- Vega Corea EJ, Rizo IA. 2006. Evaluación de 29 clones de yuca (*Manihot esculenta*), Nicaragua, 2005/2006. Managua: INTA.

CHAPTER 10

Seed potato in Malawi: Not enough to go around

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Abstract

For nine years (2007–2016), CIP and its partners—the Department of Agricultural Research Services (DARS), Department of Agricultural Extension Services (DAES), Universal Industries Limited (UIL, a private company), and Concern Universal (CU, an NGO)—had a project in Malawi to produce potato seed rapidly using hydroponics, through both a private company and government stations, and using recently released CIP varieties resistant to LB. There was increasing demand for potatoes from crisp factories and from urban markets. There was almost no formal seed sector for potatoes in Malawi. Yields were low before the project intervention (about 12 t/ha). The main problems included LB, BW, aphids, and tuber moths. The project reached 80% of its targeted 15,000 farmers, training them in seed production using PS, NS, and small plot production. Over 200 extension agents were also trained. Because of what farmers learned in the project, they are now more careful when buying seed in the market. There was a huge demand for seed potato in Malawi, and the seed-multiplying groups organized by the project received small amounts of seed, making it impossible to produce much seed for other FGs.

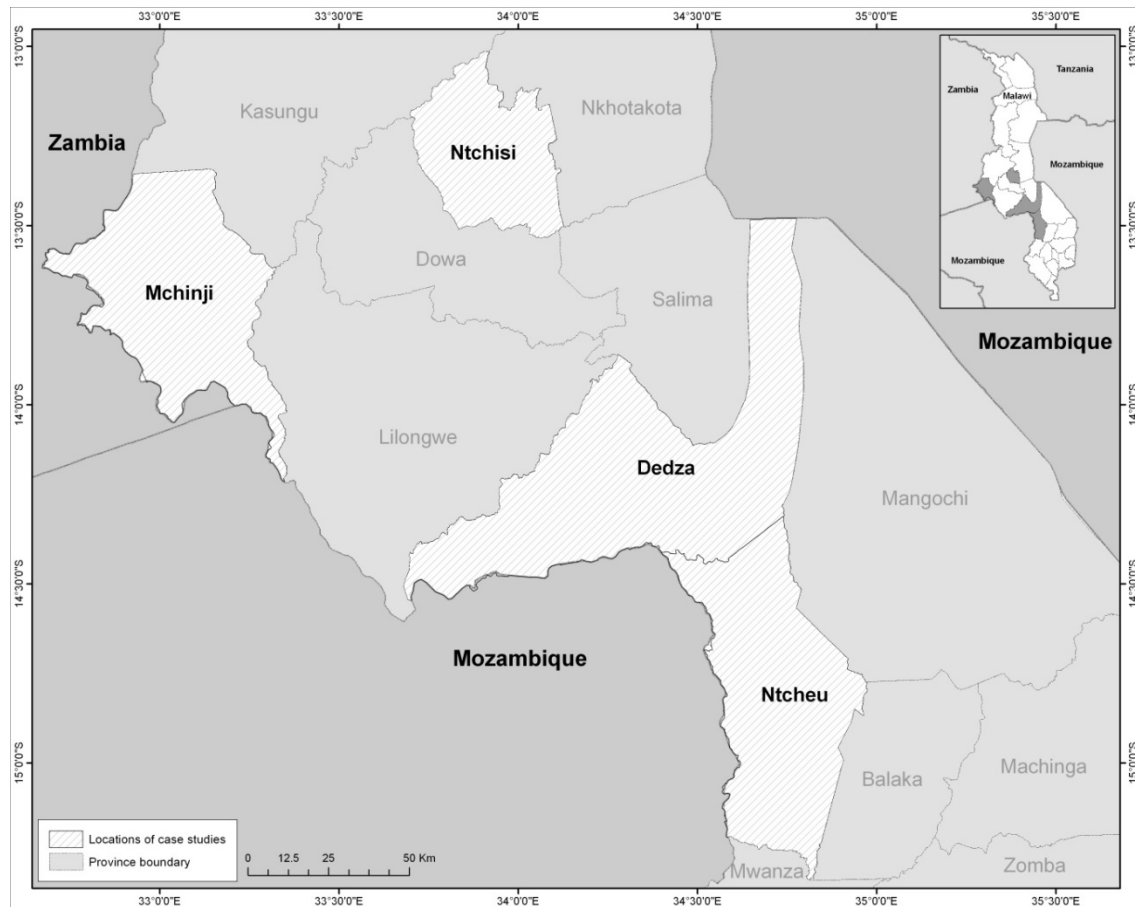
Rationale

The potato is an important food crop in Malawi, yet yields are low and seed quality is poor. Women especially have poor access to seed. There are various problems with seed potato storage.

1. The intervention

Potato production in Malawi is plagued by low productivity and poor quality (Demo et al. 2007). To address these problems, in 2007 CIP and its partners (DARS, DAES, UIL, and CU), with funding from Irish Aid, developed and implemented the first phase of a project called Improving Food Security through Enhanced Potato Productivity, Technology Development and Supply. The first phase of the intervention (2007–2012) was implemented in two districts, Ntcheu and Dedza. The second phase (2012–2016) was expanded to two more districts, Ntchisi and Mchinji. These four districts are in the top five potato

production areas. Phase II seeks to reach 45,000 smallholders with improved seed and other potato production technologies, to double productivity among 15,000 direct beneficiaries (Khonje 2013).



The intervention works with private sector partners, especially UIL, which produces seed through aeroponics using potato clones from CIP, while training farmers on good seed management (from planting to storage). The Potato Project also links farmers to markets through private sector partners such as UIL (see Figure 10.1).

This project exploits both informal and formal seed systems to give farmers access to potato seed. CIP is responsible for conducting research, providing clones, and participating in variety trials at the station and with farmers. The seed certification and quality control unit at DARS is responsible for variety testing and quality control before seed is released. This case report is largely based on a gender analysis of the potato seed system carried out in Dedza and Ntcheu in 2013. The analysis aimed to help make seed potato interventions and RTB seed systems more gender sensitive.

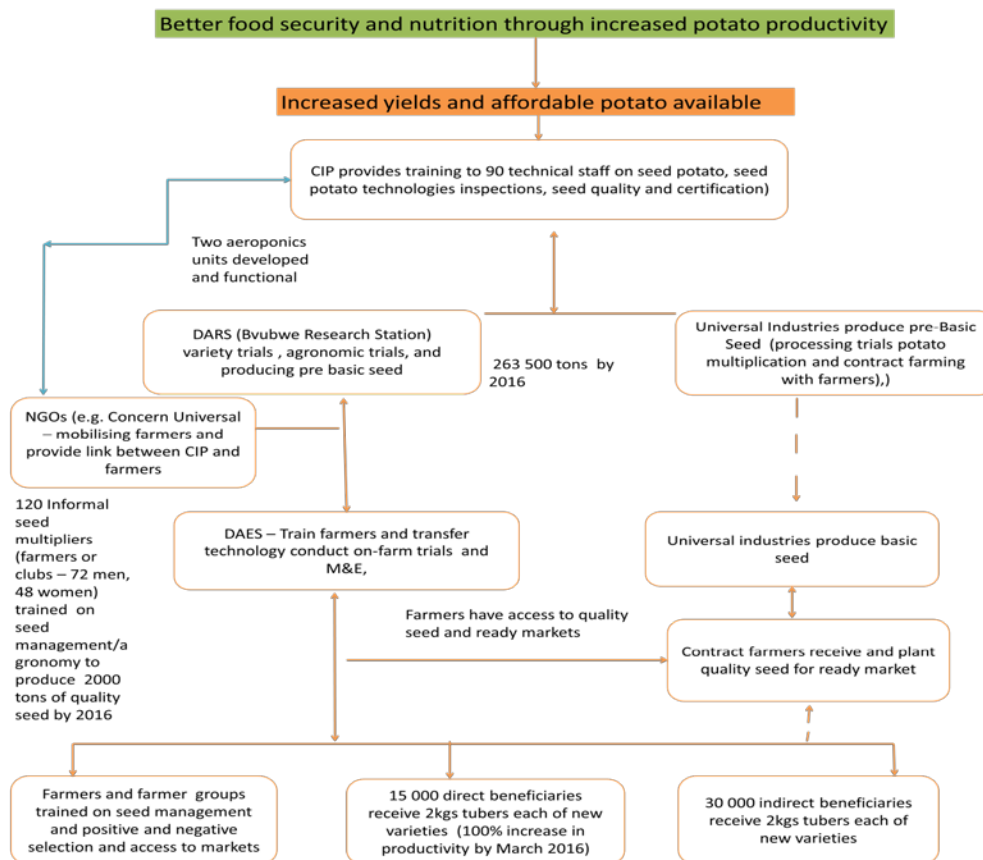


Figure 10.1. Schematic diagram of the project seed system. Source: Authors.

Theory of change

New varieties from CIP would be tested and released by the government of Malawi, and seed would be rapidly multiplied using aeroponics. FGs would receive the seed and further multiply it, and make it available to farmers, thereby increasing production and improving food security and incomes for local people. The project would link farmers to markets to improve the demand for quality seed.

The project selected and released improved potato varieties from CIP’s newly developed clones, which were tested in Malawi during eight years of conventional breeding to select materials with horizontal (durable) resistance to LB, the main potato disease. Potatoes that are not resistant to LB are often sprayed with fungicides 4–10 times a season. The project compared the new varieties with local ones (e.g., ‘Rosita’, ‘Violet’) and ‘Lady Rosetta’, which was introduced from South Africa by UIL; it was

susceptible to LB and BW and had not yet been officially released in Malawi. From year three the project worked to improve on-farm seed selection and to produce seed of local and improved varieties to supply the crisps (chips) factories, the informal market, and for farmers to eat at home. Local varieties 'Rosita' and 'Violet' proved to be acceptable for processing.

A gender component was not well integrated into the theory of change during Phase I of the project. It was, however, written into the proposal for Phase II, when the goal was that half of the farmers reached would be women.

Scaling up

In Malawi, the informal system provides 70% or more of planting material for vegetatively propagated crops, which highlights the importance of informal seed channels (CIAT et al. 2011). The project focuses on strengthening the informal system by training farmers and increasing the adoption of new varieties.

Phase I project

Farmer training in potato production. Phase I trained 80% of targeted 15,000 direct beneficiary farmers on potato production. About 42% of targeted farmers received advice from extension officers on LB and BW. The project achieved the following:

It introduced new techniques for multiplying quality potato seed and trained technicians and farmers to use them. These techniques include PS, NS, TC, and aeroponics, which has been tested and released for use in Malawi.

More than 200 extension and research workers were trained. TDARS received trainings (academic, workshop, and on the job) for potato research, seed production, and crop management. Eight MSc students completed their thesis research in the project. The NGO partner CU learned more about growing potatoes, while the private sector partner UIL and Milling Ltd learned about seed multiplication.

Seed potato field inspectors were trained in seed quality control and assurance.

The project helped to create a National Root and Tuber Crops Innovation Platform to coordinate and promote the development of root and tuber crops including potatoes.

Several CIP clones have been tested and released by DARS in Malawi and proved to be more resistant to LB than local varieties 'Rosita' and 'Lady Rosetta' from South Africa (Demo et al. 2009). Released varieties from CIP clones include 'Thandizo' (CIP-381381.13), 'Zikomo' (CIP-381381.20) (for boiled potato and French fries), 'Chuma' (CIP-395015.6), 'Njuli' (CIP-396027.205), and 'Mwai' (CIP-396036.201) (for crisps, boiled potato, and French fries).

CIP introduced the DLS to farmers. Extension workers taught FGs to build the DLS and to store seed.

Framework: Potatoes in Malawi

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Polymakers					There was no formal seed sector	
National research	Multiplied aeroponics source seed				Commercial varieties	
International research	CIP provided clones	CIP-led project never provided enough seed	Seed not available			
Traders (local markets)		Traders sold seed, but not part of project				Project had concerns about poor quality
Private seed sector						
Farmer organizations	Project organized farmers			Women farmers involved in training		Groups trained in pos. & neg. selection
Government extension				Dept. of Ext. trained farmers in selection, increased demand		
Private sector processors	UIL producing aeroponics seed	Distributing some seed to farmers				
Seed users			Had poor access to seed			

2. General context

Type of farming systems

In the main potato-growing districts, potato is the most important cash crop for farmers and their second most important food crop, after maize. Potato is the third most important food crop in Malawi after maize and cassava (Minot 2010).

According to FAOSTAT, Malawi is the biggest potato producer in SSA: in 2007 Malawi produced 2.2 MT of potato per year. Potato consumption has tripled over the past 15 years to 88 kg/capita. Smallholders produce 775,000 t of potato on 48,7000 ha (Business Innovation 2011); however, production increases in potato are due to an increase in area cultivated (Demo 2007). There is scope for improving yields. In 2007, Malawi had an average yield of 11.9 t/ha and cultivated 185,000 ha. This compares with South Africa, which had a yield of 34 t/ha and cultivated 58,000 ha.

The lack of improved varieties, clean planting material, and methods to manage diseases are among the reasons for low yield (Business Innovation Facility 2011). Major diseases include LB (*Phytophthora infestans*), BW (*Ralstonia solanacearum*), blackleg (*Erwinia carotovora*), and PLRV. Major pests are aphids, tuber moths (*Phthorimaea operculella*), cutworms (*Agrotis segetum*), and rootknot nematodes (*Meloidogyne javanica*) (Demo et al. 2009).

Most potatoes in Malawi are grown in highland areas of the southern and central regions, with altitudes between 1,000 and 2,000 masl and receiving more than 750 mm of mean annual rainfall.

Dambo is land bordering streams and rivers that is flooded in the summer and where winter cultivation depends on residual moisture (Gondwe 2005). Potato is planted with the rains in November and December, or grown in dambo or with irrigation during the dry winters in May and June. In Mchinji, Ntchisi, Ntcheu, and Dedza, women-headed HH had less dambo than male-headed HH (0.5 ha for women vs. 0.7 ha for men) (Phase II baseline data). Dambo is important in seed potato multiplication, which could explain why no women multiplied potato seed as individuals. Dambo land allows farmers to have three potato seasons per year: Potato is planted twice in the dambo land and once in the uplands (generally other crops are then planted for two years). Farmers select seed potato from ware potato after harvest, so having dambo land ensures having seed throughout the year.



The Shire River. Potatoes can be planted three times a year near the river or in dambo lowlands.

Gender and potato growing in Malawi

In Malawi potato farming is male dominated; 62% of potato farmers in Dedza are men (Maganga et al. 2012). Many women grow potatoes as part of HH headed by men. Male-headed HH recorded 30% higher yield in 2011/2012 and 20% higher yield in 2010/2011 than female-headed HH.

In both Ntcheu and Dedza, potato production that was heavily dependent on dambo lands was regarded as a man's crop (although single women could also cultivate it to look after their families).

Even where land is owned by the woman, men as heads of HH often decide how the land will be used because men often have cash earned from off-farm work to buy inputs. Extension officers favor men for training. In Malawi male-headed HH sell more agricultural produce than female-headed HH (Kherallah et al. 2001).

Market importance of potatoes for farmers

UIL is one of the few large food processing companies, making crisps from potatoes it buys from local farmers. The rising middle income and upper class Malawians are also demanding more ware potato in Malawi (Business Innovation Facility 2011). Private companies like UIL are increasingly moving into contract farming, giving potato farmers access to high-value markets. However, growth in markets may benefit men more than women because men have been better able to take advantage of the commercialization of agriculture than women (Kherallah et al. 2001).

Trends, developments, ongoing change

UIL processes about 40 t of potatoes a week. Before the start of this project, the factory only received 20 t of low-quality potatoes from farmers in Ntcheu District.

In Malawi farmers save their own seed or buy it from other farmers. Seed sold in villages and at local markets is of two types. (1) Seed produced by farmers who have been trained on seed management, (e.g., PS and NS). PS is selecting and marking potato plants as parent stock. Farmers choose their seed from plants that are growing well and have no signs of BW or viruses. NS is roguing, or removing diseased plants. (2) Seed selected from a heap of potato tubers after harvest.

Malawi does not have a potato-breeding program, and most of the potato clones that have been released in the past five years are from CIP. Although new varieties have been released, 'Violet' and 'Lady Rosetta' from South Africa are the most common; however, these have degenerated and farmers say these varieties are "tired."

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 Before the intervention

Multiplication techniques used by farmers

Men and women stored potato seed in the same way, selecting small tubers during harvest as planting material, selling the big ones, and keeping the medium-sized ones to eat. Farmers stored seed on the floor of the house in a room where there was plenty of air so the seed stayed cool. They selected a room that was not used a lot such that it was unlikely that anyone would step on or touch the potatoes.

After two weeks when farmers thought the seed was dry, they packed it in sacks so that it could quickly germinate. Other farmers put the seed into sacks immediately after harvest to allow for quick germination. To guard against pests, farmers also applied chemicals such as Actellic (pirimiphos-methyl 57%) or Super Shumba (fenitrothion 1%, deltamethrin 0.13%). Some mentioned other methods such as sprinkling the seed with ash before putting it in sacks to prevent rot and pests. Some respondents said that they built sheds like cattle pens to store their seed. Others kept the seed on dry grass. Some farmers sun-dried the potato seed before putting it in sacks.

Women who were interviewed said they were responsible for seed conservation, if it was going to be planted in the woman's plot. Women also monitored their husband's seed if he was travelling, and told their husbands if the seed was rotting or abnormal. Women also helped to care for seed destined for plots they would plant with men. The men were usually responsible for applying chemicals to seed in storage and in the field.

Seed sources and delivery channels

Farmers identified different sources of seed, including buying (from the market, from neighbors, or from other sources), saving their own seed, and receiving seed as gifts. A few mentioned other sources, including CIP and UIL.

Most farmers sold seed to each other within the village. Villagers identified neighbors with good seed and tried to buy directly from them. Farmers bought replacement seed in the village or at the market to replace their seed when it "got tired." Farmers often recycled seed for several years before needing to replace it.

Buying seed from the market was risky since farmers would not know the quality and origin of the seed. This was a concern especially for women, who said that in most cases they could not distinguish bad from good seed at the market. When buying in villages, men and women could buy from people they knew and trusted. Men learn about seed when they attend training and also when they go to markets. Farmers said they sold seed for several reasons:

- Poor storage facilities where much of the seed rotted, so it was better to sell any excess that could not be stored (mentioned by men).
- Farmers could not use all of their seed because they did not have enough fertilizer to plant it all (mentioned by men).
- To generate cash income to use to buy fertilizer (mentioned mostly by men).



Women manage much of the potato crop in Malawi. Selling potatoes in Dedza. Photo by Jeff Bentley.

- Small sales to “lessen poverty in the home” (e.g., to buy food, pay for health expenses and other items; mentioned by women, who had problems getting enough seed at planting time).

Day labor and borrowing from friends were some of the strategies farmers used to get seed. Farmers could work for others and be paid in seed. Those with no seed could ask farmers who had finished harvesting to allow seed-seekers to glean tubers from the harvested field. Women favored non-cash sources of seed more than men did.

3.1.2 What changed as a result of the intervention

Changes in knowledge about multiplication technique

Farmers said that they had been taught about small plot techniques to multiply seed. They began joining potato groups that were multiplying seed. Foundation seed was distributed to groups so farmers needed to join in order to access seed of new, improved varieties. It was difficult for individual farmers to find land where potato had not been grown for two years; but in a group one member could volunteer land that others could use to grow clean seed. They now knew the proper spacing of potato planted for seed (30 x 25 cm). Potato for seed is planted close together so the tubers will be small.

Crop rotation

Both men and women said that crop rotation protected potatoes from disease. When identifying land for rent to produce seed, groups often chose land where potato had not been grown for several years. Farmers said that potato should not be rotated with crops like tomato and tobacco because they suffer from diseases like those that attack the potato.

New seed storage techniques

Many farmers lacked access to enough good seed because seed rotted during storage. DLS were introduced to communities to ensure quality seed storage. According to CIP (2012), 47% of men and 34% of women in target communities have used the DLS on their own or as members of groups.

DLS are little structures that store seed in partial shade. None of the DLS have been built on land owned by women. Since some of the DLS have been built by NGOs, and not by the farmers, there may be a biased selection toward males. Women may not be able to guard the seed stored in the DLS, limiting their ability to adopt this technology, but they have managed use to DLS in groups.

Continuity and change

While both men and women recognize that quality seed is important, they cannot always access it. For example, while both men and women mentioned that it was preferable to use egg-sized seed, women said they preferred smaller seed because it covers a larger area. Women may also buy poor quality seed because it is cheaper.

Although other farmers are still the biggest source of seed, other sources have entered the arena. Agricultural extension officers have given some farmers seed of new varieties, and UIL is starting contract farming whereby they provide seed and other inputs to farmers who sell back their harvest to UIL.

3.2 AFFORDABILITY OF THE NEW SEED POTATO

In Dedza and Ntcheu, both men and women recognized that quality seed increased yields and sizes of tubers. PS can be beneficial to all farmers, but especially for women, who often have poor soil and cannot always afford quality seed.

Gender norms and profitability of new seed

It is not clear whether men and women benefit differently from selling potatoes. One marketing group in the project managed to make some money, but when the potatoes were sold, the husbands usually received the money, and not the wives. Women cultivating their own plot benefited more from selling potatoes than those working a family plot, because the husband would make all decisions regarding the income from potato. Some men who were living in their wives' communities said that it was difficult to benefit from potato income.

In Dedza, Ntcheu, Mchinji, and Ntchisi, 68% of men and 33% of women said they had received training on marketing and profit calculation, revealing a gender bias in training (CIP 2012). However, this may be an overestimate: in the qualitative study only one group of farmers mentioned that they had received training on markets, which involved farmers identifying markets and negotiating with traders as a group. This group had made training visits to the Catholic Development Commission and received a two-day seminar in Blantyre on marketing. This was the only group that reported successful marketing. Groups (even beneficiaries) often mentioned their failure to identify markets and to take advantage of them. They said that marketing training was important and they wished to have it.

Are farmers able to afford the new seed?

Women often said they could not afford potato seed. Both men and women expressed a willingness to pay more for good quality, but while men generally said they could pay between 5,000 MK (\$14.80) and 8,000 MK (\$23.60) for a 25-liter bucket of good seed, most women said this was unaffordable. Women sometimes quoted 1,000 MK (\$2.96) as the price they would pay, but others said even that was too expensive. Women's groups consistently said that many families could not afford to buy seed.

Women prefer non-cash transactions – such as paying for seed with labor or asking their friends for loans of seed to be returned after harvest. Most men said they could do odd jobs to get cash to buy seed. Women said they could rely on their friends to get seed to repay after harvest, but it was usually difficult for men to give another man seed to plant. Single women said that they would do piece work for cash, or for inputs such as seed and fertilizer.

3.3 SEED QUALITY

Men and women constantly said that because of poor seed quality, yields of the popular varieties were declining.

3.3.1 Before the intervention:

Before the intervention, farmers obtained seed tubers from potato heaps after harvest, selecting only for size with no screening for disease, resulting in a high incidence of unhealthy seed.

In focus groups farmers mentioned a problem with “tired seed” or seed that has “lost its power.” The problem was especially common with ‘Violet’ and ‘Rosetta’ varieties. Farmers had little knowledge of controlling diseases like LB and BW, or pests like whitefly. Farmers did not know about PS and NS. Diseases were a major challenge and could wipe out an entire crop. Farmers knew that disease was related to poor planting material.

Both men and women farmers knew about pesticides. Karate (an insecticide, lambda-cyhalothrin) and Dithane (a fungicide, mancozeb) were commonly used to control chiwawu (LB) as well as insect pests. Women often said they did not have money to buy chemicals or, when they bought the chemicals, they might not have access to knapsack sprayers. Women saw this as a major problem.



The pale green halo of Phytophthora, potato LB.
Photo by Jeff Bentley

Women said that the lack of adequate time to harvest meant that farmers would harvest in a hurry, mixing the tubers without selecting when stored. This allowed diseases to spread to other seed, resulting in rot. Women said that the risk of theft in the field, particularly of the new varieties like ‘Chuma’, may force them to harvest their seed early, also resulting in seed rot.

Effect on seed quality and production

Project beneficiaries obtained higher yields than non-project farmers. Projects typically select the most productive farmers, and project beneficiaries had higher yields than the others at the start of the project (on average 12.4 t/ha vs. 10.4 t/ha). But between the 2010/2011 season and 2011/2012, the beneficiaries increased their productivity by 12.8% compared with 1.8% for non-beneficiaries.

Farmers’ ability to benefit from good seed

Poverty constrains farmers’ use of seed. When there was no food, families often used their money to buy food instead of seed. Women (especially) sometimes knowingly buy bad seed because it is cheap.

Farmers mentioned a lack of fertilizer and land. Even those who had the skills to multiply seed potato could not multiply it at a commercial scale. Lack of loans and other capital limit the ability of farmers to access seed.

Gender and social capacities and constraints to use good seed

In Dedza and Ntcheu, both men and women said that when they use “tired seed” or seed that has “lost its power,” yields were often low. PS can benefit all farmers, especially since men and women sometimes cultivate different plots. Learning to select one’s own seed is particularly relevant for women

farmers, who often have poor soils and sometimes cannot afford to buy seed. In Malawi women often had plots separate from the jointly cultivated family plot, where they could plant crops of their own choice.

Both men and women took great care to ensure that seed did not rot; they stored seed in dry places with air circulation. However, some women said that lack of knowledge on how to store seed sometimes resulted in seed losses. In focus group discussions, women said that in spite of all the precautions taken, most of the seed was lost to rot. In one group women mentioned that they did not have seed multipliers in their area because the only person who had tried to store the seed in a maize granary had lost all of it to rot. In another group women described losing the new seed the first time they grew potatoes:

Participant: The potato that we stored most of it rotted.

Facilitator: How did you store it for it to rot?

Participant: It was our first time to grow potato, we had enough rains. The rains left early and all the leaves dried before the potato was ripe. We went to harvest it thinking it was ripe, and when I took the potato home I spread it on the floor. But it was rotting and I removed it from there and put it in the maize granary, where it continued to rot and I didn't know how to store it.

Facilitator: But you still have seed?

Participant: Yes, even though most of it rots I still have enough seed.

Men have the primary responsibility for maintaining HH seed quality, although women help them by, for example, reminding them to buy chemicals to spray seed.

Men had more access to DLS than women. None of the DLS were built on land owned by women. Since some of the DLS were built by NGOs and not by the farmers themselves, there may have been a bias toward male-headed HH. However, women have managed to access this technology as part of groups, in part because it is easier for a group to guard against theft of seed from the DLS.

Men and women knew the same things about spraying chemicals, but women often lacked the money to buy chemicals or access to knapsack sprayers. Women regarded this as a major problem. Where men and women from the same HH cultivated different plots, the men's plots got preference when it came to spraying for diseases. Women often said that in families where men and women had separate plots, there was no cooperation, leaving women with a higher burden of taking care of family consumption needs and little to invest in agriculture.

Differentiation of information

Men and women had similar knowledge about maintaining seed quality. Family members were a key source of knowledge before Phase 1. Men thought it was their responsibility to teach women how to take care of the seed when the men were away. Farmers could also learn from neighbors and within groups. Men were more likely to get new knowledge from the market as they were normally the ones to buy seed.

3.3.2 What changed as a result of the intervention

New knowledge and changes in seed selection techniques

Farmers' knowledge on quality seed has improved. Farmers now prefer PS and NS instead of choosing seed from a heap. Even farmers who did not belong to groups mentioned a change. In the past they selected smaller tubers as seed, and after training they now select medium-sized tubers (the size of an egg) even when buying seed from the local market.

When buying seed at the market, farmers now look at the eyes, with a preference for strong shoots and fewer shoots in order to have big tubers and a healthy crop. In villages, they inspect the fields of potential seed sellers when shopping for seed.

Farmers said their yields improved when they used both NS and PS. Sick plants were often uprooted to prevent diseases from spreading to other plants, particularly for diseases that did not have a chemical cure (e.g., BW).

Continuity and change

Although farmers recognize the advantages of the new potato varieties, most have not fully adopted them. There is a huge demand for the seed but low supply. The seed is expensive and not always available for purchase in enough quantities. Although farmers joined groups in order to access new seed, the groups complained that the available seed was not enough even for group members, "so we end up planting varieties that are not yielding much." Groups received just 70–1,200 tubers (which is not much for a whole group). Groups said that it took them a long time to multiply enough seed to share with other farmers. Farmers expressed despair, and some members left groups in disappointment after they had failed to get the seed.

Farmers were usually able to access new potato varieties through extension officers or NGOs that gave seed to FGs and offered training; however, farmers said that extensionists delivered the seed late. Many farmers have still not been trained on NS and PS.

4. Seed producers and seed availability

4.1 THE MODEL

The model has two major components, high technology and decentralized farm-level techniques.

High technology

Rapid multiplication through aeroponics is implemented with UIL and DARS under the Ministry of Agriculture and Food Security. UIL manufactures and distributes biscuits, confectionaries, and potato crisps. UIL is increasingly engaging in aeroponics (growing plants in the air) to provide quality seed to farmers. Aeroponics produces seed rapidly (as one tuber can develop 100 minitubers) and yields high-quality potato seed tubers that are free of pathogens.

Decentralized farm-level techniques

CIP introduced PS and NS through FGs to improve seed quality. CIP promoted the DLS to keep seed quality high in storage.

Scaling up

Scaling up should consider gender. For example, women had less access to dambo land (wetlands) for growing potatoes. In many districts, women's potato yield was half that of men. Training manuals should be gender sensitive and encourage the participation of both men and women.

Although FGs can empower both men and women, reproducing stereotypical gender roles in groups (e.g., leadership, decision making, and access to training) may make groups less beneficial to women. The groups were effective for sharing information but less so for marketing. Many of the groups in this study received no significant benefits. Women need to be directly invited to training (not only HH heads or group leaders). The project should identify local women leaders who can help mobilize women to participate in project activities. Since women are more likely to be members of credit groups and associations, the project can target these groups to reach many women.

Ensure that there is enough seed to distribute.

Rapid multiplication techniques

NS and PS are appropriate because many smallholders cannot buy seed and need to be able to save their own quality seed.

Aeroponics can be further encouraged and developed. It is highly technical and demands constant electricity; but the commercial sector can use this technique to supply decentralized seed producers.

Market intelligence

The qualitative study showed that there is high demand for quality seed potato in villages. Demo et al. (2006) noted that Mozambique imported most of its seed from Malawi. There is a possibility for growth of potato seed markets.

4.2 BENEFITS FOR THE FARMERS

Seed from aeroponics is free from disease, but farmer-managed seed (using PS and NS) often increases yields by 30%.

Increased yield

New technologies may help farmers to manage their varieties well and to maintain high yields. Increasing yields can empower women. Women said that increasing potato yields, especially on plots that they control, could address women's needs and help them achieve self-reliance. Women want potato varieties with high yield, good taste, and resistance to diseases.

PS and NS might reduce the work load of spraying crops for diseases. Healthy seed will help men and women, who mentioned potato pests and diseases as a major problem.

Disadvantages of the seed

The study found that men are perceived to drink more alcohol when their incomes increase. Even men who do not drink control HH expenses and do not always agree with women about how to spend income from potatoes. Some men resisted buying clothes, salt, relish, soap (i.e., for HH consumption). Women and children did not always benefit from increased potato incomes, and women demanded their own plots of land. Women farming their own plots can make their own decisions, but women do not have access to cash for chemicals, fertilizers, and good seed.

4.3 QUALITY ASSURANCE AND REGULATION

DARS is involved in variety testing, registration, and release. Before release, varieties are tested for three years on station and two years on farm in different agro-ecological zones. Participatory testing, including farmer assessments, ensures that the varieties meet farmers' needs. Higher yielding and disease-resistant clones from CIP are being multiplied through aeroponics at Chitedze Research Station and by UIL. However, a major weakness is the shortage of qualified technical personnel for potato research and development (Demo et al. 2009). CIP is training researchers at Chitedze to conduct research and testing of potato, and CIP has trained agricultural extension officers in potato production.

Quality is difficult to ensure in local markets and villages. Where farmers have a communal DLS, there are no quality assurance mechanisms to ensure that only quality seed is stored there.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

Malawi has various regulations governing seed certification and quality control:

- Seed Act, 1988 (Act No. 5 of 1988).
- Seed Regulations, 1994 (Act No. 5 of 1988)
- Amended Seed Act, 1996 (Act No. 9 of 1996)
- Seed Order, 1997 (Declaration of Prescribed Seed).

The Seed Act (1988) defines seed as “the part of any plant intended for planting and includes other propagating material” (Malawi government, No. 9 of 2996 Amended).

Annex IIIa of the National Seed Policy (1993) encourages strong linkages between the public and private sectors in research, extension, and quality control. The Department of Agriculture is heavily engaged in promoting improved, market-oriented varieties.

The Seed Services Unit (under DARS) is responsible for seed certification and quality control. Although there is a seed certification scheme, there are too few government seed inspectors and a lack of infrastructure and laboratory equipment (Mloza-Banda et al. 2010).

The Secretariat of the Agricultural Technology Clearing House (Department of Research) is mandated with registering new varieties and protecting the interests of farmers (Maideni et al. n.d.). However, the register is not always up to date and it is difficult to cross-reference with other varieties being released in the region.

To combat poverty, Malawi has rolled out several seed support services for farmers, particularly the maize seed subsidy. These have not been extended to potato seed.

5.2 SEED HEALTH AND QUALITY

The Plant Protection Act of 1964 needs to be updated (Mloza-Banda et al. 2010). Seed regulations and procedures need to be reviewed in order for Malawi to be able to participate fully in regional seed trade. Malawi legislation needs to be harmonized with regional seed policies.

Problems include the shortage of plant health inspectors and the lack of enforceable guidelines for seed potato at the farmer level. There are no QDS standards.

6. Seed multiplication tools and techniques

Minitubers are produced in the aeroponics unit at Bvumbwe Research Station by DARs (under the Ministry of Agriculture and Food Security and CIP) and by UIL at their Njuli premises. The minitubers are then taken to the field for multiplication. The first seed harvested in the field is called generation 1 (G1); this is normally handled by CIP. At G4 the seed is taken to farmers for further multiplication. FGs multiply seed with PS and NS. The main problem was that FGs received absurdly small amounts of seed and could not begin to meet the demands of seed of new varieties.

7. Lessons

Although the intervention raised knowledge among farmers and created demand, there was not enough seed to meet the demand, so many farmers continued to use degenerated seed.

Make more seed available

Decentralized seed multiplication relying on smallholders did not speed up the availability of new, disease-free, quality planting material. Multiplication is very slow.

Training should target both men and women.

Researchers and partners should ensure that demonstration plots are hosted by both men and women to ensure that women's needs are also addressed.

Adapting technologies to local contexts

Farmers are not adopting DLS because it is expensive, theft-prone, and the building material is unavailable.

Continue to promote seed sales and good seed management

Producing seed with aeroponics could ensure the availability of seed, except for women who want to use non-cash strategies for getting seed, such as working for seed or accessing social networks.

Commercial seed may not reach these women, although some farmers may buy this clean seed and later sell relatively clean planting material to other farmers.

Information and Communication Technologies

Groups needed to open a bank account, but this was a barrier for those who could not do so. Companies that buy from farmers should use information and communication technologies such as mobile money transfer to allow non-banking groups to participate. Women would also be more likely to get access to money sent directly to their cellphone.

References cited

- Business Innovation Facility. 2011. Value Chain Analysis: Tomato, Onion and Irish Potato in Jenda, Mzimba District, Malawi MicroVentures Market Linkages Project, Report for the Microloan Foundation.
- CIAT, WALA, CRS, and Government of Malawi. 2011. Seed System Security Assessment, Southern Malawi. Blantyre: CRS and CIAT. (Available from <http://seedssystem.org/wp-content/uploads/2014/03/SSSA-Southern-Malawi-Final-Report-.pdf>)
- CIP. 2012. Improving Food Security through Enhanced Potato Productivity, Technology Development and Supply Chain in Malawi. Baseline Survey Report.
- Demo P, Low JW, Mwenye JO. 2007. Potato production in Malawi: Strengths, weaknesses, opportunities and threats, pp. 339-345. African Potato Association Conference Proceedings, Alexandria, Egypt.
- Demo P, Dominguez C, Cumbi S, Walker T. 2006. The potato sub-sector and strategies for sustainable seed production in Mozambique. Report of a two-week potato sub-sector study conducted from 21 November to 4 December 2005. (Available from www.iiam.gov.mz/documentos/darn/relatorios/potato_satrategies_production.pdf)
- Demo P, Pankomera P, Mwenye O, Chiipanthenga M, Khumar N, Chimwala L. 2009. Performance of CIP-derived population B potato (*Solanum tuberosum* L.) clones under Malawi conditions. Presented at the Symposium of the International Society for Tropical Root Crops held in Lima, Peru, 2–6 November 2009.
- FAO. 2011. Gender Inequalities in Rural Employment in Malawi: An Overview Prepared by the Gender, Equity and Rural Employment Division of FAO. Rome.
- Gondwe H. 2005. Why free inputs failed in the winter season. In: Levy S, ed. Starter Packs: A Strategy to Fight Hunger in Developing Countries? : Lessons from the Malawi Experience 1998–2003. Wallingford, UK: CABI. p. 193–202.
- Kherallah M, Minot N, Kachule R, Soule BG, Berry P. 2001. Impact of agricultural market reforms on smallholder farmers in Benin and Malawi. Project Number 97.7860.6-001.00 IFPRI Collaborative Research Project Final Report Volume 1.

- Khonje AA. 2013. Research trends in horticultural crops in Malawi. *Journal of Crop and Weed* 9(2):13–25.
- Maganga AM, Edriss AK, Matchaya GC. 2012. Unexploited profit among smallholder farmers in central Malawi: What are the sources? *International Journal of Applied Economics* 9(2):83–95.
- Maideni FW, Kaudzu G, Timeyo Phiri GA. n.d. The seed status report for Malawi.
- Mloza-Banda HR, Kaudzu G, Benesi I. 2010. Evaluation of Malawi seed sector for the Common Market for Eastern and Sothern Africa (COMESA) harmonised seed regulations and policies. Final report for the African Seed Trade Association.
- Ngwira N. n.d. Gender and Poverty Reduction in Malawi. (Available from www.un.org/esa/socdev/social/meetings/egm10/documents/Ngwira%20paper.pdf)

CHAPTER 11

Releasing disease-resistant varieties of cassava in Africa

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Abstract

The Unleashing the Power of Cassava in Africa (UPoCA) project was part of the long-term, international effort to manage the food price crisis that started in 2008. The project shared 59 new cassava varieties with at least 11,540 smallholders across seven African countries. The project worked with subcontracted seed farms, which kept the cassava roots and some of the stems, turning over most of the stems to the project to deliver to other farmers, especially those linked to cassava-based industries. The project established 290 community seed multiplication farms to receive the stems from contractors, and multiply seed for community members. Various pests and diseases limit cassava production in Africa, but cassava mosaic disease (CMD) is the most serious. The new, high-yielding varieties distributed by the project were endowed with resistance to CMD, to other diseases, or to drought. Farmers received training in the rapid multiplication of the stems, to enhance community access to the new material. The project also trained various processors to make cassava graters and mills, and to process high-quality flour and other products from cassava. Over time the new varieties (and rapid multiplication, combined with the stimulus of producing for market) increased the production of cassava in the project countries.

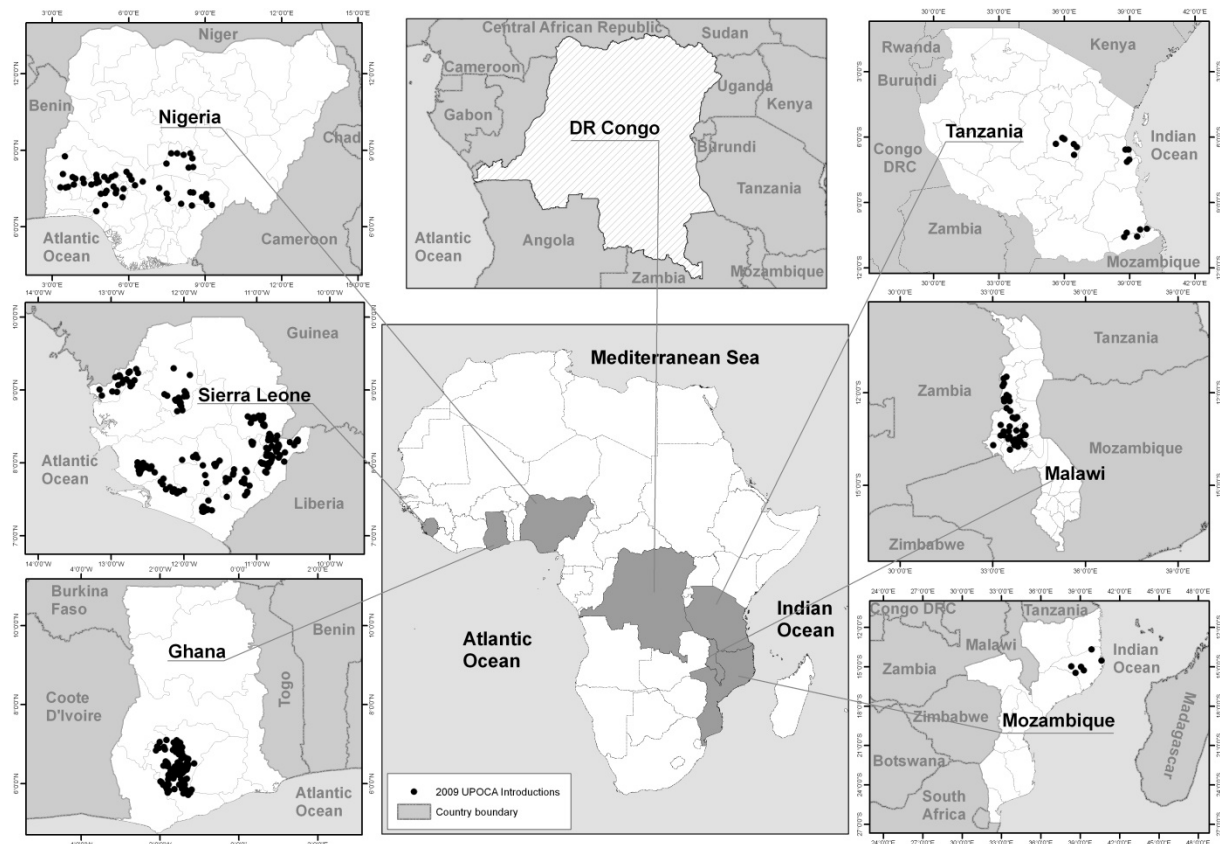
Rationale

There have been many efforts to produce improved cassava varieties, but this has been constrained by low productivity and marketing difficulties. This led to UPoCA in response to the food price crisis, a project funded by USAID in 2008 and led by IITA. Cassava has great potential and diverse uses, and it can increase commercial opportunities through farm-level enterprises. This is vital to sustainably increased food availability, reducing rural poverty and unemployment, and enhancing agro-industrial and socioeconomic growth. UPoCA covers DR Congo, Tanzania, Ghana, Nigeria, Sierra Leone, Malawi, and Mozambique.

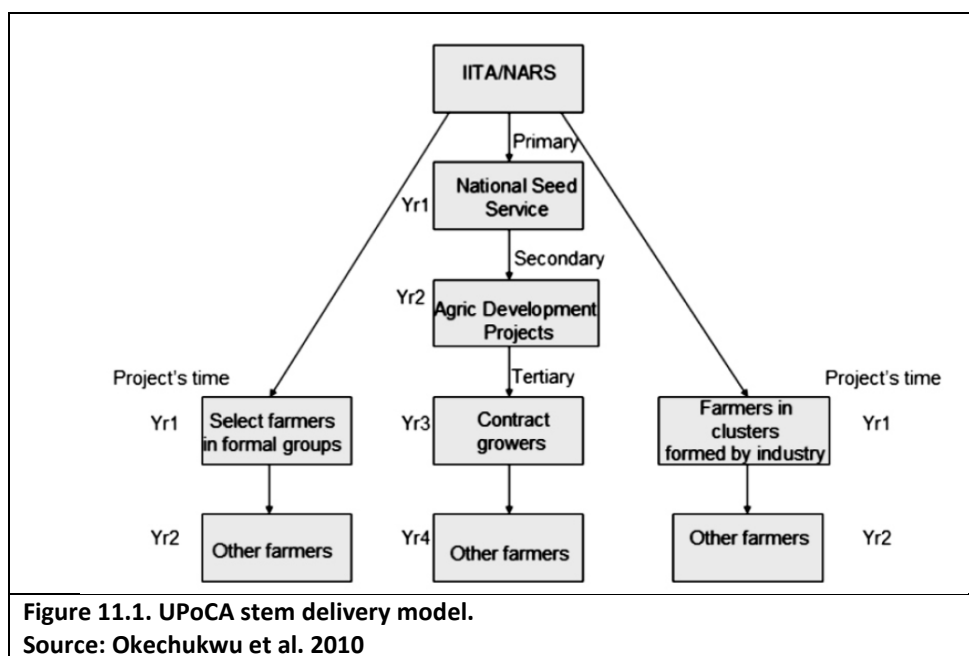
1. The intervention

The project disseminated 59 elite varieties from 290 community multiplication fields on 710 ha to at least 11,540 small farms. The farms were planted by smallholders linked to 55 partner organizations and 11 agricultural firms. Through experiential learning during 24 hands-on short-term courses, 345 men

and 142 women learned improved techniques for cassava production (e.g., integrated cassava crop management, including pests and diseases, and rapid field multiplication of stems); processing (learning to make graters, presses, and mills); product development (e.g., high-quality flour, starch, tapioca, cassava fritters, doughnuts, and bread); and packaging-&-labeling. Eight technologies were introduced to rural communities. The intervention sites within the seven countries were selected on the basis of population of vulnerable HH, preliminary cassava trials, access to markets, processing interventions, existence of partners, and probability of success. The project sites are shown in the maps below.



The intervention was for two years, from 1 August 2008 to 31 December 2010. The aim of the project was to provide an adequate supply of cassava products at affordable prices by making improved cassava varieties available, and teaching new techniques for cassava processing (see Figure 11.1).



The UPoCA project partnered with government departments of agriculture and extension, NGOs, community-based organizations (CBOs), farmer associations, and private companies in order to mobilize farmers and multiply and distribute selected varieties to farmers. Timing was season driven; in the first year multiplication was made to dovetail into the planting season of the second year. In each country the seed farms were supervised by UPoCA staff to ensure good plant population and plant health. Partner organizations monitored these farms and provided other inputs. Seed farms had to produce 10,000–15,000 plants/ha. The project owned 60–90% of the stems, whereas the subcontractor took all of the roots and the remaining stems. In the following planting season (2010), stems from these farms were harvested for wide distribution to other farmers, especially those linked to cassava-based industries. The seed farms also served as demonstration sites for farmers.

The project was not designed specifically for seed production as a business; however, the training curriculum did include producing stems for commercial sale. The project disseminated improved varieties by setting up demonstration trials and distributing stems to farmers, with further multiplication by out-growers. The main reason for stem multiplication and distribution was to promote high-yielding improved varieties.

By the end of September 2009, UPoCA had links with several farming HH and farmer-based organizations. Improved varieties backed by farmer trainings in integrated cassava crop management can lead to on-farm yields of at least 30% above the existing varieties (Okechukwu et al. 2010) (Table 11.1).

Table 11.1. Summary of UPoCA achievements at the end of September 2010

Common indicators	Overall target	Overall achieved by end Sept 2010	% Delivery on overall Project target
SO 1.1: Number of rural HH benefiting directly from intervention			
IR 1: Access to improved production technologies and Practices increased			
IR 1.1: No. of rural farmers & processors benefiting directly from interventions	395,000	350,018	88.6
IR 1.2: No. of vulnerable HH benefiting directly from Interventions	184,925	28,265	15.3
IR 1.3.1a: Male attendance at short term training	620	979	>100
IR 1.3.1b: Female attendance at short term training	305	800	>100
IR 1.3.2: Type of training	5	24	>100
IR 1.3.3: No. of trainings	42	44	>100
IR 1.3.4: Other trainings	900	428	47.6
IR 1.4: No. of seed farms established	26	290	>100
IR 1.5: Area of seed farms established (ha)	176	710.2	>365.6
SO 1.2: Gross margin /ha for targeted (cassava) commodities			
IR 2: Increased agricultural productivity			
IR 2.1: Gross margin per hectare for targeted commodities (\$)	200	0.0	0.0
IR 2.2: No. of technologies made available for transfer	6	16	>100
IR 2.3: Crop productivity (t/ha)	20	24.2	>100
IR 2.4: Area (ha) under improved cassava varieties	27,000	12,566.2	46.5
IR 3: Improved agric. marketing & commercial viability of micro/SME			
IR 3.1: No. of agricultural firms benefiting directly from interventions	35	58	>100
IR 3.2: No. of partner organizations & active institutional members of those partner org.	36	71	>100
IR 3.3: No. of producers' organizations, trade & business associations, & CBOs assisted	13	239	>100
IR 3.4: No. of PPP formed	19	2.0	10.5
IR 3.5: No. of jobs	27,000	26,956	99.8
IR 3.6: Sales (\$) of agricultural commodities /products /services	17,320,000	70,579.2	0.4
IR 3.7: No. of fabricators linked	12	21	>100
IR 3.8: No. of products introduced and improved	5	24	>100
IR 3.9: No. of Information resources developed	5	13	>100

Source: Proc. 11th ISTRC-AB Symposium, Kinshasa, DR Congo, 4–8 October 2010.

Legend: IR, intermediate result; SO, specific objective

Framework: Cassava in seven African countries

Stakeholder	Availability/ supply	Accessibility			Quality: variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Policymakers	Seed was produced within each country to avoid quarantine	Policy allowed the seed to be distributed				QDS applied; Tanzania allows formal status to QDS
National research	Received varieties from IITA	Adoption of technology and products			Access to new improved varieties	
International research					IITA provided 59 new cassava varieties	Varieties resistant to CMD
Traders (local markets)						
Private seed sector	Not involved					
Farmer organizations		290 community seed farms produced seed				
NGOs	NGOs and nat. ext. supervised seed farms	NGOs and nat. ext. oversaw distribution to farmers	Seed was given to farmers for free	NGOs and national extension trained farmers		
Private sector processors				Small-scale processors trained by project		
Seed users		Farmers received seed from community seed farms				

2. General context

Farming systems

In 2009, cassava production in Africa was about 122.9 MT (51% of the world total) on 12.5 million ha; Nigeria was the largest cassava producer (44.6 MT). Most cassava varieties were traditional clones

that had been selected by farmers. The superior cassava germplasm and varieties developed by IITA were available to national scientists for breeding, selecting, and testing.

Most of the world's cassava is grown by smallholders who use techniques that give low, but stable, yields. In cassava-producing areas, good roads are few and far between, and soils are poor. Land preparation is occasionally mechanized, but all other tasks are always done with hand tools. Nearly half of the farms planted with cassava are in lowland tropical areas and have pronounced dry seasons. The savanna areas have tremendous potential for cassava production, with a pronounced three- to six-month dry season.

Nigeria. Cassava contributes more than 45% of agricultural gross domestic product (AGDP). Cassava production has been on the increase in the past 20 years with more land cultivated and higher yields.

Cassava is a major crop in Ghana. It is a main source of carbohydrates and a regular source of income for rural dwellers, contributing (22%) to the AGDP.

In **DR Congo**, subsistence farming involves 4 million families on plots averaging 1.6 ha. Subsistence farmers produce mainly cassava, maize, and sorghum. Cassava is the most common food—even the leaves are eaten.

In **Malawi**, cassava is the most important root crop and is a staple food for about 30% of the 10 million Malawians. Cassava is gaining in importance due to its performance under drought conditions and its low cost of cultivation compared with maize, which is expensive to cultivate without government subsidies.

In **Mozambique**, cassava is the most important staple food, along with maize, rice, beans, and millet. Production is concentrated in four provinces in central and northern Mozambique.

In **Sierra Leone**, cassava is produced on about 400,000 ha with a yield average of 5.2 t/ha. Many local varieties are cultivated, but there is now a major improvement program run by the National Research Institute.

In **Tanzania**, cassava is an important food crop. The estimated annual growth of cassava consumption from 1980 to 2000 was 3.4%.

Market Importance of cassava for farmers

Gari (a cassava meal) has high market demand among rural and urban HH. The use of cassava is constantly expanding into bread-making and biscuits, pastries, and snack foods (Eggleston and Omoaka 1994; Onabolu et al. 1998). Cassava-based products include starch in paper board, textiles, and pharmaceuticals; liquid glucose in the soft drinks industry; and many more (Kleih et al. 2013).

General seed sector characteristics

Cassava is propagated by stem cuttings. The main sources of the planting materials are farmers' fields, neighbors, and sometimes rural markets. The leaves and upper part of the cassava plant are removed before harvesting so the harvester can easily grab the stem and pull the roots from the ground. The roots are then separated from the root base. All this is done by hand, as machines may damage the roots. The cuttings for the next crop are selected during harvest. The multiplication rate of

planting materials is low compared with grain crops. Cassava stem cuttings are bulky and dry up within a few days.

Cassava is grown all year round. In most areas, little effort is made to preserve cassava stem cuttings after harvest of the roots (Eke-Okoro et al. 2005).

Pests and diseases

The average production of cassava in Africa is currently below the world average (FAOSTAT 2015).

The major pests of cassava in SSA are the cassava green mite, mealybug, spiraling whitefly, root scales, and the variegated grasshopper. Whitefly (*Bemisia tabaci*) is a major vector of two major groups of viruses responsible for important diseases in cassava. The main diseases are CMD, cassava bacterial blight, cassava brown streak disease (CBSD), cassava anthracnose disease, and fungal root rot. CMD alone accounted for an estimated 47% of East and Central Africa's cassava production losses during the severe outbreak from the early 1990s until the introduction of highly resistant varieties in the late 1990s (Legg et al. 2015). CMD continues to be a pervasive problem in several regions due to the scarcity of improved varieties. In the early 2000s, CBSD emerged as a major threat to cassava production around the Great Lakes region and was expanding westward (ibid.). Efforts are ongoing to develop dual CMD- and CBSD-resistant varieties. Meanwhile, clean seed systems (i.e., production and distribution of CMD-resistant, CBSD-free planting material) has emerged as a major strategy to control the CMD and CBSD menace in East and Southern Africa.



Symptoms of cassava mosaic virus.
Photo by Jeff Bentley

Trends, developments, ongoing change

Problems with the distribution of planting materials of elite varieties mean that farmers continue to grow local varieties that are low yielding and susceptible to pests and diseases. Smallholders in Africa also lack access to diversified markets, even though cassava is becoming a cash crop. Problems include livestock damage, theft, pests and diseases, lack of planting materials, lack of extension, erratic rainfall, lack of processing machines, poor access to market, poor roads, declining soil fertility, lack of capital, and weak government support.

African governments' short-term response to the 2008 food price crisis included banning cereal exports; removing duties and taxes on cereal imports; providing food aid, cash for work, food for work, and feeding programs; selling strategic grain reserves at subsidized prices; subsidizing seed, fertilizer, fuel, and electricity; and increasing minimum wages. The governments responded in the medium- to long-term with agricultural input subsidies and development programs to increase domestic food production and raise incomes. Governments expanded public sector seed production and distribution; strengthened extension services; established food reserves; and improved irrigation, roads, and

telecommunications. This project was part of the international effort to manage the food price crisis in the long run.

3. Seed users

3.1. SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 Before the intervention

Few private companies are interested in producing cassava seed because of its low multiplication ratio, because the cuttings take a year to produce and require a lot of land, and because the planting material is bulky.

There were previous interventions in SSA to multiply and distribute cassava stems before UPoCA. The Eastern Africa Root Crops Research Network (EARRNET) during 1994–2007 operated in Burundi, DR Congo, Ethiopia, Kenya, Madagascar, Rwanda, Southern Sudan, and Uganda, to transform cassava into a broad-based commercial commodity. EARRNET was successful, but the ever-increasing demand for improved cassava materials was a challenge.

IITA scientists played a leading role in developing improved cassava varieties that resist diseases and pests and are low in cyanide, drought-resistant, early maturing, and high yielding. Disease-resistant varieties yield about 50% more than local varieties. Distribution of CMD-resistant varieties helped production levels recover to pre-epidemic levels in less than five years. Improved cassava varieties are now used in most cassava-growing countries in SSA.



Resistant varieties may stay disease free for generations.
Photo by Jeff Bentley.

3.1.2 What changed as a result of the intervention

UPoCA benefited 363,625 farmers and processors—92.1% of the target. At least 36,401 HH (including 9,696 vulnerable ones) received improved cassava planting materials and technical assistance in DR Congo, Ghana, Malawi, Mozambique, and Nigeria. The average root yield of improved varieties sampled on farms was double the national averages (18.9 t/ha in DR Congo and 13.8 t/ha in Sierra Leone).

In **DR Congo**, 10,180 farming HH (including 7,270 vulnerable ones) received 2,099,000 m (i.e., the length of the cut stems, if placed end-to-end) of planting materials through project partners in Bandundu, Bas Congo, and Kasai Oriental provinces. The beneficiaries established 1,430 new ha of the improved varieties ‘Butamu’, ‘Disanka’, ‘Mbankana’, ‘Nsansi’, TME 419 (‘Obama’), and ‘Zizila’. People from all over the country have come to UPoCA seeking planting material.

In **Ghana**, the project distributed 26,724 bundles of improved cassava planting materials in 13 districts; 6,365 farmers received 4 bundles each.

In **Mozambique**, the project disseminated 1,790 bundles of cassava stems of five varieties from its primary multiplication sites to 44 HH heads (33 men, 9 women) across Nampula. The varieties are 'Badge', 'Chigoma', 'Mafia', 'Likonde', 'Nikwaha', and 'Nachinyaya'. The intervention taught the trainees better methods of cassava processing to produce high-quality flour.

In **Malawi**, the project accessed 80 ha of cassava fields established in 2009 in the four impact areas—Dowa, Kasungu, Mzimba, and Ntchisi—and distributed cuttings there. On demand, cassava stems were also shared with farmers of the CAVA roject and the Millennium Villages project in Zomba, and through the FAO to farmers in Nkhotakota District.

Sierra Leone. UPoCA and partners started the Tongea Women's Development Association in Sandeyalu. This group has helped the residents to become gainfully employed with a new micro-processing center for cassava, opening up 5 ha of land to cassava growing and providing improved varieties to more than 500 farmers. IITA conducted training on cassava processing and packaging.



After the distribution. Farmers walk home with their new cassava stems.
Photo by Carl Walsh.

In **Nigeria**, 4,856 HH (including 2,426 vulnerable ones) benefited from the project in seven states. UPoCA distributed improved cassava varieties and trained farmers and processors on processing, packaging, and labeling. The project linked processors to farmers for a steady supply of cassava roots.

In **Tanzania**, an FG increased its earnings by more than tenfold. By introducing new recipes that use cassava flour, the project created additional demand for the flour, boosting cassava production.

Yield assessment

In **DR Congo**, average root yield from farms with improved varieties was double that of farms planted with landraces. The highest yields were recorded on improved varieties (47 t/ha) in the rainforest belt of Orientale province and 29 t/ha in coastal forest of Bas-Congo.

In **Nigeria**, farmers who received improved varieties and training in four of the seven states (Ekiti, Ondo, Osun, and Oyo) had yields of 22–26 t/ha (twice the national average in 2007 of 12 t/ha).

In **Sierra Leone**, the root yield for project farmers was 13.8 t/ha, compared with the FAO-reported national average of 5 t/ha. Highest root yields (>15 t/ha) were from Bonthe, Kailahun, Kenema, Kono, and Moyamba districts.

Value-added processing of cassava

In **Ghana**, UPoCA helped to improve quality management and compliance in cassava processing at Caltech Ventures in Ghana.

In **Sierra Leone**, two micro-processing units for cassava were commissioned in the Kailahun District. One site at Sandeyalu for the Tongea Women’s Development Association (60 women, 8 men) was commissioned by President Ernest Bai Koroma (23 October 2010) and handed over by the US Ambassador (2 November 2010). The second commissioned site was at Sagila, in the Peje West Chiefdom, in Kailahun District.

In **Tanzania**, UPoCA linked two beneficiary cassava-processing groups at Muheza Tanga, Nachingwea and a progressive farmer, Rev Senyagwa, with Districts Agriculture Development projects, thereby helping to ensure sustainability of best practices within these projects’ priority activities. At Kongo village, Bagamoyo District, where the project had established a community cassava stem multiplication site, UPoCA collaborated with the district authority to install a quality grater, pressing machine, and a hammer mill.

Training

Three short courses were completed for 35 participants (29 men, 6 women) in Ghana, Mozambique, and Nigeria. The participants included farmers, cassava processors, government, private sector, NGOs, and research staff. Six other training sessions were held for 1,315 beneficiaries in Ghana, Nigeria, and Tanzania.

In **Mozambique** (11–30 October 2010) three artisans—Eduardo Manuel, Dionisio Bernardo, and Horacio Selemene—learned to make cassava processing machines such as a grater and a dewatering press. An IITA technician conducted a cassava processing and product development course for 14 participants (8 men, 6 women) at Nogovolas village. The participants learned to make cassava flour, starch, tapioca, gari, soya fortified gari, cassava croquettes, cassava fritters, cassava chin-chin, cassava doughnuts, cassava egg rolls, and bread.

In **Nigeria**, a 5-day ToT workshop (29 November–3 December 2010) for 18 participants (16 men, 2 women) covered cassava product packaging and labeling as well as planning and management of a small cassava enterprise. There, 18 participants from FGs, public extension, and cassava processors learned about such products as odorless fufu, soybean fortified gari, cassava tidbits, cassava flour, chin chin, strips, and egg rolls.

In **Ghana**, 95 processors were trained in product development and standard compliance at field days. A total of 526 farmers and processors (320 males, 206 females) were trained on rapid multiplication and the use of grades and standards in product development. A 1-day orientation workshop on quality management was organized for 11 cassava processors at Caltech Ventures.

In **Nigeria**, 558 persons (417 males, 141 females) were trained on rapid multiplication and competitive commercial cassava cultivation in Kogi State.

In **Tanzania**, ToT graduates conducted two training sessions (value-added processing and quality management) for 125 participants (58 men, 67 women) at Dodoma, Nachingwea, Muheza, and Kibaha.

Project training introduced the national crop protection services in Ghana and Sierra Leone to “Green Muscle” biopesticide for area-wide control of the variegated grasshopper *Zonocerus variegatus* on cassava.

In **Malawi**, the project supported the construction of solar driers at three processing centers—Mbwandimbwandi, Chisi Investments, and Kankhuyu Creations—and rehabilitated one at Masimbe Investments to enhance cassava processing.

Sales of Agricultural Commodities, Products, and Services

In **DR Congo**, 21 t of fermented microchips, 15.5 t of high-quality cassava flour, and 14 t of fermented cassava paste were produced by UPoCA-assisted processing centers and managed by partners FDM and PRODI.

In **Malawi**, Masimbe Investments continues to sell an average of 175 kg/month of cassava starch to the sausage-making company, Kapani Meat Products, for \$126/month. He sells at a lower price than if he had a wider choice of markets. Mbwandimbwandi is selling an average of 250 kg of cassava flour, earning about \$260/month.

In **Nigeria**, farmers sold \$37,000 worth of roots in Osun State.

3.2 AFFORDABILITY OF THE NEW SEED

UPoCA established 290 cassava seed farms on 710.2 ha in the seven project countries (Tables 11.1 and 11.2).

Table 11.2. Introduction of improved cassava varieties in new locations

Country	No. of Varieties	Name of Varieties
DR Congo	17	Butamu, Disanka, Liyayi, Lueki, Mayombe, Mbankana, Mvuama, Mvuazi, Ngandajika, Nsansi, Rav, Sadisa, Sawa Sawa, Sukisa, TME 419 (Obama), Zizila, 2001/0330
Ghana	4	Afisiafi, Bankyehemaa, Esambankye, Tek bankye
Malawi	5	Manyokola, Mbundumali, Mulela, Sauti and Silira
Mozambique	4	Likonde, Nikwaha, Chigoma Mafia, Nachinyaya
Nigeria	19	TMS 97/2205, TMS 98/0581, TMS 98/0505, TMS 98/0510, TME 419, TMS 92/0326, TMS 96/1632, TMS 98/0002, TMS 92/0057, NR87184, TMS 96/1089A, NR 930199, TMS 4(2)1425, TMS 30572, TMS 91/02324, TMS 92B/00068, TMS 98/4763, TMS 92B/00061, TMS M98/0068
Sierra Leone	8	SLICASS 1 to 6, TME 7, TME 419
Tanzania	2	Kiroba, Kikombe

Source: James and Bramel, UPoCA Terminal Report (2011).

3.3 SEED QUALITY

3.3.1 Before the intervention

The major threats to seed quality before the intervention were viruses causing CMD, CBSD, cassava bacterial blight (*Xanthomonas manihotis*), green mites, and mealybugs. Yield reductions of cassava

infected with CMDs under field conditions ranged from 24% to 75% (Seif 1982). All of these pests and diseases survive on the planting materials from one season to another.

At the time of UPoCA implementation, most farming communities were aware of the potential damage that pest and diseases could cause in their fields. Farmers knew that pests and diseases spread with the stem cuttings and that the best management option was clean planting material. The project made the difference by creating awareness and distributing material that was free of pests and diseases.

3.3.2 What changed as a result of the intervention

UPoCA multiplied and distributed healthy, high-quality planting material of improved cassava varieties to the farm level (Table 11.2). The material was produced with rapid field multiplication. This involves selecting stems of improved varieties, cutting the stems into two- or three-node stakes, administering a mix of insecticide and fungicide to prevent pests and diseases, planting the stakes in a nursery, transplanting sprouted stakes to the field at a spacing of 1 x 0.5 m, and field management (IYA Cassava Value Chain Members 2014).

This clean, high-quality planting material was continuously and rapidly distributed in all the UPoCA countries. Over time, this will increase production in those countries, and improve the quality of cassava products for local industry and export.

4. Seed producers and seed availability

The intervention was aimed at increasing the competitiveness of cassava value chain actors by mobilizing available, field-proven technologies which were previously developed by IITA (James and Bramel 2011). The planting materials were made available by IITA working with national research institutes in all seven UPoCA countries.

4.1 THE MODEL

UPoCA introduced 58 elite cassava varieties from 290 community stem multiplication fields on 710.2 ha to at least 13,590 ha of smallholder farms. The intervention overcame the poor supply of clean planting materials by establishing community seed farms, training national extension agents, NGOs, and CBOs in RMTs and quality control of seed farms, and by conducting mass education and communication of improved practices and appropriate sources of technical information, inputs, and credits through NGOs, community radio, media houses, and micro-finance agencies.

Scaling up

Scaling up in the seven UPoCA countries comprised the following:

- Selecting sites based on (1) beneficiary interest in cassava, (2) prior cassava research for development, (3) participation in the project's baseline surveys, (4) partnership opportunities with ongoing activities by agricultural development agencies, and (5) probability of synergies with other agencies.
- Area-wide dissemination of technologies to help increase cassava productivity and value-added processing.

- Building cadres of ToT graduates to facilitate experiential learning in FFS.
- Linking value chain actors, especially producers and processors, to encourage improvements in cassava enterprises.
- Mass media communications to promote cassava use and to discuss constraints and ways to address them.

Other projects in the UPoCA countries may help to scale out this intervention. For example, in Nigeria, there are the following activities:

- Increasing cassava starch through the multiplication and distribution of IITA-improved varieties
- Cassava Enterprise Value Chain Development project at Otu Ogbooro and Igboho communities, Itesiwaju, Shaki East and Orelope LGAs, Oyo State
- Sustainable Cassava Seed System in Nigeria
- Nigeria Cassava Transformation Initiative, and many more.

Two other initiatives are worth noting. In Sierra Leone, there is Unleashing the Power of Cassava: Value addition and commercialization of cassava in Sierra Leone (UPoCA-SL)-Phase 2. Tanzania has the Community Action in Cassava Brown Streak Disease Control through Clean seed.

4.2 BENEFITS FOR THE FARMERS

Improved pests- and diseases-free planting materials were given to the farmers free of charge. This was of immense benefit to farmers who have always planted cassava stems from diseased plants. More seed farms were established in each of the UPoCA countries, making access to planting materials easy for the farmers. Market opportunities increased as agro-industries were involved in the intervention. The introduction of new cassava-processing technologies in rural communities will reduce postharvest losses for the farmers.

4.3 QUALITY ASSURANCE AND REGULATION

UPoCA laid the foundation for other projects that offered opportunities for establishing enduring regulations. The intervention improved institutional capacities to develop food quality management systems; create compliance awareness; and promote adoption of product grading, sanitary and phytosanitary certification, traceability, packaging, and branding systems for domestic and export markets. Under the USAID project Maximizing Agricultural Revenue and Key Enterprises in Targeted Sites, the project harmonized sanitary and phytosanitary standards and grades for domestic, regional, and international markets.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

Nigeria. The National Seed Service Unit was created in 1975, with a mandate of producing foundation and certified seeds and to arrange for seed certification. The demand for improved seeds rose so much that the Unit found it difficult to satisfy the farmers. The ADPs also had to produce seed, mostly for maize and rice (Bentley et al. 2011). The national seed policy formulated in 1992 provides guidelines for developing the seed subsector, but it has little to say about cassava. Recent guidelines of the National Agricultural Seeds Council provide standards for cassava stem multiplication and procedures for private, commercial production. However, more than 90% of cassava seed stems are produced informally.

Tanzanian law encourages seed to be produced at the village level as QDS. (Tanzania was one of the few countries to legitimize QDS certification.) The village selects farmers to produce seeds of various crops to be sold to other farmers at affordable prices. Locally bred varieties are tested for three seasons before being released. Varieties released in other East African countries whose seed systems are harmonized with that of Tanzania need only one season of verification before being registered. The legislation recognizes other regional harmonized seed systems, including the East African and QDS regional systems.

The seed system in **Malawi** is strongly influenced by the government, although private sector participation is encouraged. The government's sector-wide agriculture policy gives direction and subsidizes fertilizer and seed (mostly of maize) to promote the use of new varieties (and hybrid maize) and to ensure food security within the country.

In **Mozambique**, seed sector is largely a farmer-saved seed system. The formal seed sector is dominated by the government and two large seed companies, SEMOC and PANNAR.

In **Ghana**, Parliament passed a national seed law (Plants and Fertilizer Act 2010) that is in line with the 2008 ECOWAS regional seed harmonization regulation. The new law opens the door for an increased role for the private sector in seed production. It will encourage international seed companies to introduce new varieties and hybrids.

5.2 SEED HEALTH AND QUALITY

The project ensured that cassava cuttings distributed were at least free from quarantine viruses. To avoid the risk of inadvertently spreading pathogens, the project produced stems in-country for domestic distribution. Among the countries where the project operated, phytosanitary standards for cassava stem cuttings were followed in Nigeria and Ghana. However, in other countries standards were not in place or they were not enforced. In general, there is poor enforcement of seed health standards for clonally propagated crops in SSA. Following the outbreak of CBSD in East Africa, a greater emphasis is being placed on seed health standards.

6. Seed multiplication tools and techniques

Planting material of new varieties was produced through rapid field multiplication (e.g., pre-sprouting in a nursery before transplanting stems of two or three nodes). In-vitro propagation could have been used, but because of technicalities and cost there was limited use of this method to produce planting materials for international distribution. There is the need to use other cost-effective means of producing non-bulky planting materials. Leaf-bud cuttings for the rapid propagation of cassava could be valuable (Pateña and Barba 1979).

7. Lessons

The project achieved almost 100% of its targets (James et al. 2010); however, it did not reach enough vulnerable HH. And because of poor baseline data, the project could not document all of those poor HH that were reached. The project could not show that it had contributed to an increase in sales of agricultural commodities, products, or services because of poor market data. Nor could the project calculate the gross margin per hectare for targeted commodities because it collected little data on gross margin per hectare of cassava planted. The number of vulnerable HH benefiting directly from interventions was not documented because of little effort to differentiate vulnerable beneficiaries from others.

A successful seed project can be based on the strategy of getting new, disease-resistant varieties onto farms as quickly as possible, over a wide geographical area. Improved cassava varieties developed mainly by IITA were resistant to pests, diseases, and drought. The varieties were early maturing, low in cyanide, and yielded up to 50% more than the local varieties. Distributing virus-resistant varieties helped yields recover to pre-epidemic levels in less than five years. Improved cassava varieties are now used in most SSA countries that grow cassava.

A combination of contracting with seed farms and creating community seed farms can provide seed of new varieties on a massive scale. The project supervised seed farms, which had to produce stems of an agreed quality and density (10,000–15,000/ha). The project kept most of the stems to deliver to community seed multiplication farms.

References cited

Bentley JW, Ajayi O, Adelugba K. 2011. Nigeria: Clustered seed companies. In: Van Mele P, Bentley JW, Guéi R, eds. *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford, UK: CABI. p. 38–64.

Eggleston G, Omoaka P. 1994. Alternative breads from cassava flour. In: Ofori F, Hahn SK, eds. *Tropical Root Crops in a Developing Economy. Proceedings of the Ninth Symposium of the International Society for Tropical Root Crops held in Accra, Ghana, 20–26 October 1991*, Ibadan: IITA. p. 243–248.

Eke-Okoro ON, Ekwe KC, Nwosu KI. 2005. Cassava Stem and Root Production: A Practical Manual. Umudike, Nigeria: National Root Crops Research Institute (NRCRI) Press. 54 pp.

FAOSTAT. 2015. Cassava production statistics. Available from (<http://faostat3.fao.org/download/Q/QC/E>) (Accessed on 18 November 2015)

IITA. 1990. Cassava in Tropical Africa. A Reference Manual. Ibadan: IITA. 176 p.

IYA Cassava Value Chain Members. 2014. Rapid Multiplication of Cassava Stems. Ibadan: IITA. 9 p.

James BD, Bramel P. 2011. Unleashing the Power of Cassava in Africa (UPoCA): A Project in Response to the Food Price Crisis. Terminal Report, USAID/IITA, 93 p.

James BD, Bramel P, Witte E, Asiedu R, Watson D, Okechukwu R. 2010. Unleashing the power of cassava in Africa ... are we there yet? In Proceedings of the 11th ISTRC-AB Symposium held in Kinshasa, DR Congo, 4–8 October 2010. p. 300–311.

Kleih U, Phillips D, Wordey MT, Komlaga G. 2013. Cassava Market and Value Chain Analysis, Ghana Case Study, Final Report. Natural Resource Institute, University of Greenwich, UK, and Food Research Institute, Accra, Ghana. 66 p.

Legg JP, Kumar PL, Makesh Kumar T, Tripathi L, Ferguson M, Kanju E, Ntawuruhunga P, Cuellar W. 2015. Cassava virus diseases: Biology, epidemiology, and management. *Advances in Virus Research* 91:85–142.

Okechukwu RU, James B, Ntawuruhunga P, Mahungu N, Boahen S, Kanju E, Osei-sarfoh A. 2010. Distribution and Potential Impact of Cassava Variety Spread by UPoCA. In: Okechukwu RU, Ntawuruhunga P, eds. *Proceedings of 11th Triennial Symposium ISTRC-AB*, p. 325–328.

Onabolu A, Abass A, Bokanga M. 1998. *New Food Products from Cassava*. Ibadan: IITA, 40 p.

Pateña LF, Barba R. 1979. Rapid propagation of cassava by leaf-bud cuttings. *Philippine Journal of Crop Science* 4(2/3):53–62.

Seif AA. 1982. Effect of cassava mosaic virus on yield of cassava. *Plant Disease* 66:661–662.

CHAPTER 12

Banana tissue culture: community nurseries for African farmers

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Abstract

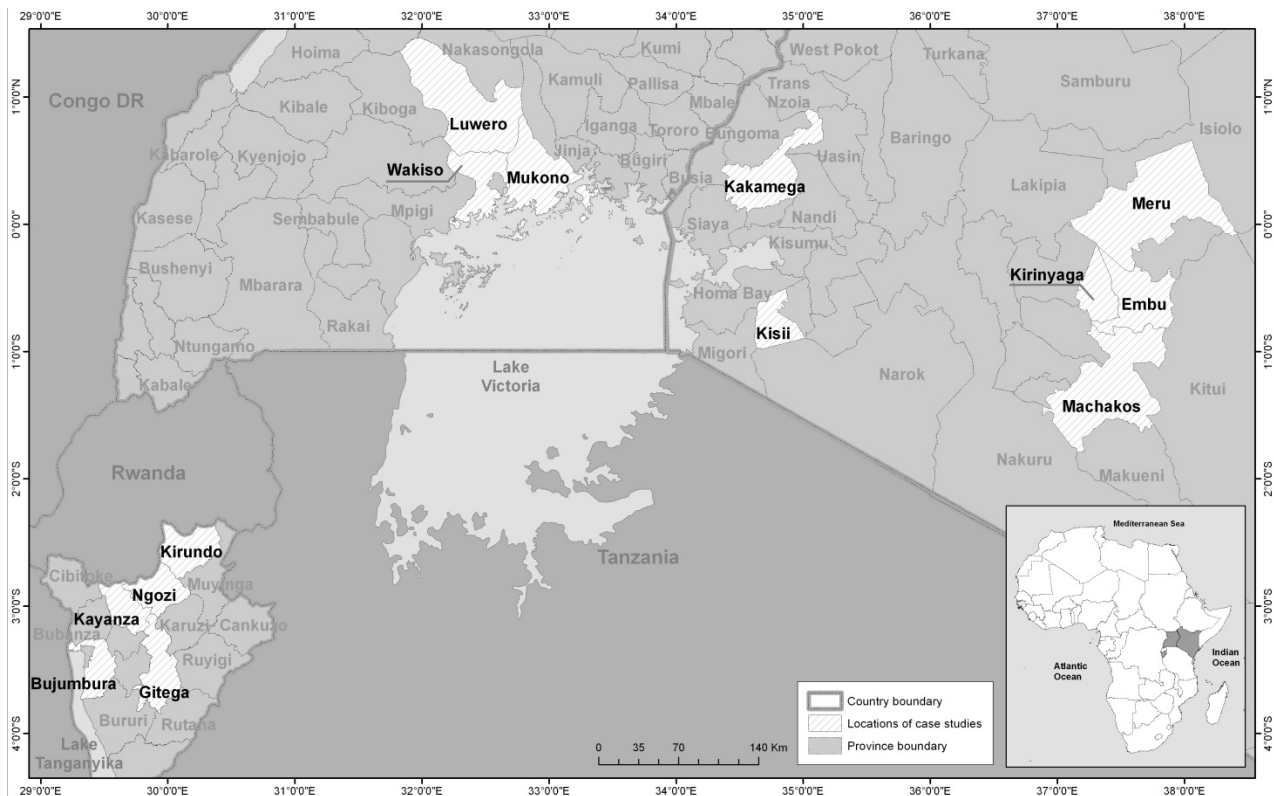
This project was carried out in three countries—Kenya, Uganda, and Burundi—to get disease-free, TC banana plantlets to farmers. Private companies were already producing TC banana plantlets, but there was no channel to distribute them to farmers. The project established community nurseries to receive the in vitro-plantlets, wean them, and harden them (i.e., grow them outside of the flask until the plantlets are big and strong enough to be transplanted to farmers' fields). Eleven new community nurseries were established in Uganda and Kenya to buy the in-vitro plants, harden them, and sell them to farmers. The most successful community nurseries were the ones near their source of TC plantlets and near their farmer customers. About 1,000 farmers were trained to transplant TC bananas to the field and care for them. Although the banana plants are disease free when removed from the flask, they are not disease resistant, and can become infected. The plantlets need extra care when transplanted (e.g., more water and fertilizer). TC was profitable for farmers who were near an urban market, which allowed them to earn higher prices for their harvested bananas. On the other hand, TC plantlets were not profitable for remote farmers.

Rationale

Tissue culture of bananas is a relatively new technology in East Africa. It allows banana planting material to be cleaned of pathogens, especially *Xanthomonas* and other bacteria. BXW is a new and serious pest of bananas in East Africa. When the project started, there was no real pathway for TC plantlets to get from the producers to the farmers.

1. The intervention

Banana is a staple food crop in the East African Great Lakes region (Burundi, Rwanda, northeastern DR Congo, Uganda, Kenya, and Tanzania). Because bananas are perennial and can be harvested year round, the crop is popular with smallholders. However, since the 1970s, banana yields in the region are low and stagnating, largely due to pests and diseases and declining soil fertility (MoA 1994; ISAAA 1996). Most small-scale banana growers plant new gardens with suckers from old plants, exacerbating pests and diseases. Moreover, suckers are bulky, making it slow to disseminate improved varieties.



TC banana planting material is clean and permits rapid dissemination. TC-planted bananas are uniform, harvested early, and the fruit is highly marketable. Specialized private companies can multiply planting material by using TC. And although TC plants are superior to suckers, their success depends on correct management by farmers and demands efficient community pathways to distribute this enhanced planting material.

In January 2008, a new TC banana project aimed to improve the livelihoods of small-scale banana growers in East and Southern Africa by developing improved market pathways to deliver high-quality TC plants based on private partnerships supported by improved institutional policies. Private companies were producing and selling TC plants as a business. All of the TC material distributed to farmers was of the Cavendish varieties, which are the main ones sold in supermarkets. They were old varieties, and not resistant to BXW.

The project had six objectives: (1) produce uniform and high-quality planting materials; (2) supply TC planting material to small-scale farmers through farmer-managed community nurseries; (3) create a training program so smallholders could manage TC planting material in the field; (4) give farmers a new source of clean planting material; (5) establish farmer cooperatives linked to community nurseries; and (6) create new, larger, and dedicated markets for farmer cooperatives. Six countries were targeted: Burundi, Kenya, Mozambique, Rwanda, Tanzania, and Uganda. A three-year study (January 2008–December 2010) for these objectives was conducted in Burundi, Kenya, and Uganda, and is the subject of this chapter.

Theory of change

At the start of the project, TC material was not readily available due to weak dissemination channels. The project proposed research to establish efficient dissemination and distribution, based on community nurseries.

Scaling up

A successful TC satellite nursery model was developed in Kenya and later used in Uganda. TC nursery operators and farmers were trained in TC banana weaning (293 trainees), and about 1,000 farmers were trained in TC banana production in the three countries.

Before they can be planted in the field, the plantlets produced by TC laboratories need to be weaned and hardened. The plantlets are weaned by putting them in a humidity chamber until they are 4–5 cm tall, then placed in large bags and hardened in a shaded nursery until they are 20–50 cm tall. The TC plantlets are free of bacteria and fungi, but they can carry viruses. Intensive testing (by certified indexing centers) is needed to be reasonably confident that the plantlets are virus free (Vézina and Dubois 2015). But once in the field, TC bananas can be easily re-infected with disease. The project produced a training manual for farmers, suggesting weeding, watering, and extra fertilizer to strengthen the plant. The manual also recommended removing the male bud of the plant (to prevent bees and other insects from foraging for pollen in the male flower, which can infect the plant with bacterial wilt) (Lule et al. 2013).

As a result of the project, 11 new nursery businesses were established in Uganda and Kenya. The TC nurseries were successful because they were near their suppliers (the laboratories that produce TC plantlets) and they were in the communities where the farmers bought their plants. A cost-benefit analysis of nurseries in Uganda revealed profits of about \$0.25 per plant, which increased as more plants were sold. The 11 new FGs were able to access credit. The impact of training was assessed on 87 farmers' fields over two crop cycles in Burundi and Uganda, revealing a doubling in yields for farmers who grew TC banana and received training, compared with control farmers. Trained TC farmers who were in groups tripled their revenue, compared with controls.



After the flask: TC bananas are delicate, and must be “hardened” in nurseries before planting in the field. Photo by Jeff Bentley.



A poster in Uganda shows BWX symptoms, and urges farmers to twist off the male flower with a forked stick.

Photo by Jeff Bentley

Framework: Banana tissue culture in East Africa

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Polymakers						Project was allowed by existing policy
National research	NARO provided some TC material in Uganda					
International research		Project trained labs, nurseries, farmers		IITA wrote 2 manuals for farmers	Existing, commercial varieties	TC cleans material of disease
Traders (local markets)						
Private seed sector	TC labs produce in- vitro plantlets	Labs sell TC plantlets to community nurseries				
Farmer organizations	Community nurseries bought plantlets	Nurseries harden the plantlets to sell to farmers	Nurseries are cited near labs & farmers			
NGOs and national extension				Extension trained farmers to use TC bananas		NAADS (Uganda) KARI, JKUAT* (Kenya) trained farmer
Private sector processors				Thriving market in fresh bananas & plantains		
Seed users	Bought plantlets from community nurseries		TC plantlets are profitable for farmers near markets			

*NAADS is the National Agricultural Advisory Services. KARI is the Kenya Agricultural Research Institute and JKUAT is Jomo Kenyatta University of Agriculture and Technology. NARO = National Agricultural Research Organization.

2. General context

Farming systems

Most of the banana varieties grown in the East African highlands are endemic. The region is a secondary center of banana diversity (Smale and Tushemereirwe 2007). There are two types of endemic banana varieties: cooking bananas (matooke) and beer bananas. The region is one of the largest producers and consumers of bananas in the world, and it is dominated by smallholders.

This is low-input, low-output farming, with about 12 banana varieties planted per plot. Bananas are mainly grown to eat, with surplus sold in local markets. Other farming systems include the plantation system, which uses one variety and uniform management, and the backyard system in peri-urban areas, which grows bananas on small plots for food and as a source of leaves for wrapping and cooking.

In **Uganda**, the seven selected intervention sites were based in the central region: three sites in Luwero District, three in Mukono District, and one in Wakiso District. These farming systems have high food and cash crop diversity, with bananas, coffee, maize, cassava, sweetpotato, and beans (Bagamba 2007).

In **Burundi**, there were six intervention sites: three in the north (Kayanza, Ngozi, and Kirundo), two in the center (Gitega), and one in the west (Bujumbura). Farms in Burundi are generally small (under 2 ha) and intensively cropped. They produce little marketed surplus besides bananas and coffee. Bananas are planted at higher densities closer to the homestead, sometimes in association with taro or cassava, where they benefit from wood ash, plant residues, and domestic waste. Further from the homestead, they may be planted farther apart and intercropped with beans, maize, cassava, and sorghum (Rishirimuhirwa and Roose 1998). Smaller farms use more of their land for bananas, whereas larger farms devote more space to beans, forestry, or fallow. Smaller farms have higher land productivity, but larger farms are generally better at exploiting economies of scale (Verschelde et al. 2011).

In **Kenya**, the six intervention sites were located in Embu, Kirinyaga, Meru, Tala, Kakamega, and Kisii. Banana systems in Kenya include subsistence farming and backyard gardening, with few commercial plantations. Where land is scarce, bananas are grown on field edges, as hedges, along paths, and where HH wastewater and garbage are dumped. Banana is the most important horticultural crop and is grown throughout Kenya's eight provinces, although Nyanza, Central, Eastern, and Western provinces account for 90% of national banana production (Qaim 1999). The project sites were in those four provinces, where banana is grown as a subsistence crop, mostly (78%) by women. Roughly 1 in 3 farmers use manure, 1 in 10 use agrochemicals, and cultivation is rain-fed. Recent fluctuations in coffee and tea prices have led to an increased popularity of banana as a cash crop.

Market importance of bananas and plantains for farmers

The growing urban markets are making bananas a more important source of cash for smallholders (Kalyebara et al. 2007). About 26% of the population depends on bananas for food and income in rural areas, and about 65% of city people eat cooked banana every day (Clarke 2003). Most people in Burundi grow their own bananas (80%), both cooking bananas (81%) and beer bananas (69%) (CIALCA 2007).

East Africa has a dynamic cross-border trade in cooking and beer bananas (Jagwe et al. 2008). Burundi is a net importer, bringing in cooking bananas from Rwanda and Tanzania and beer bananas from Tanzania and DR Congo. Kenya imports cooking and dessert banana from Uganda and Tanzania. Kenya also exports some bananas to the Middle East and the European Union. Uganda exports some of its bananas to DR Congo, South Sudan, Kenya, and Rwanda, and to a niche market of East African emigrants in Europe and the USA.

General seed sector characteristics

Banana plants are vegetatively propagated using a sucker, originating from the corm of the mother plant. Most banana-producing HH in the region grow local varieties, which are susceptible to pests and diseases.

Trends, developments, ongoing change

In the past two decades, the East African perennial banana cropping system has been threatened with various new diseases. The recent arrival of BXW is a serious threat to banana production.

Some farmers lost their whole crop if their varieties were very susceptible to BXW (such as beer bananas). The disease started in Ethiopia in the 1960s on both bananas and enset; it was then reported in Uganda and in the North Kivu province of DR Congo in 2001, and it was reported in northwestern Rwanda in 2002. The disease spread further in other banana-growing regions of Uganda, western Kenya, and Burundi between 2002 and 2006 (Tushemereirwe et al. 2003; Mbaka et al. 2009; Carter et al. 2010).

This project had a strong focus on clean planting material, but not on host-plant resistance to BXW. The potential of TC to contribute to productivity growth stimulated different organizations to promote TC in East Africa (Smale and Tushemereirwe 2007). In Kenya, the International Service for the Acquisition of Agri-biotech Applications (ISAAA) started a project in the late 1990s, producing and disseminating TC plantlets to banana farmers. Later, KARI and Jomo Kenyatta University of Agriculture and Technology (JKUAT) also became involved in TC bananas. From 2003 to 2007, Africa Harvest—an international NGO—and other agencies promoted TC in central and eastern provinces. Over 10,000 farmers were trained, and the area under TC banana rose from about 3,200 ha in 2004 to 4,290 ha in 2006 (Njuguna et al. 2010). KARI and JKUAT have spun off laboratories and set up FG-managed TC nurseries in several parts of Kenya, whereas Africa Harvest collaborates with private companies to provide TC plantlets to farmers who are organized in groups.

Before the start of this project, there were four TC banana laboratories in Uganda, where banana TC was started in 1991 by Makerere University as part of a project to mass produce disease-free planting material. In 1995, the National Banana Research Program of NARO, in collaboration with IITA, started to multiply disease-free TC banana planting materials for research, field evaluation, and dissemination. However, as a result of increased demand for TC plantlets, a commercial TC laboratory, Agro-Genetic Technologies Limited, was established in 2002. By 2009 it had distributed about 370,000 TC banana plantlets to farmers (Sonnino et al. 2009).

Two private companies, Agrobiotech and Phytolab, cover most of the banana TC market in Burundi, with some provided by the public Institut de Recherche Agronomique et Zootechnique. Agrobiotech was established in the late 1990s to produce and disseminate clean planting materials. Production of banana

plantlets increased from 80,000 plantlets in 1999 to 330,000 in 2007. Government agencies and NGOs are the main buyers of the TC plantlets, which are distributed to farmers free of charge or subsidized.

During the 36-month (2008–2010) TC banana project coordinated by IITA in Uganda, Kenya, and Burundi, farmers were linked to TC nursery owners to deliver high-quality TC plants to boost banana productivity and to improve the livelihoods of small-scale banana growers. These TC bananas are free of BXW when given to farmers, but can become easily infected in the field (Lule et al. 2013).

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

What did the interveners know?

Through its collaboration with national and private partners in Uganda and Kenya, IITA had conducted extensive research in banana TC. Substantial progress had been made in identifying problems and solutions using TC banana in Phases I and II of the project “Managing Micro-organisms to Enhance Plant Health for Sustainable Banana Production in East Africa.” The project demonstrated the superiority of TC over conventional banana planting materials among smallholders in Uganda. Research in Uganda showed that distributing planting materials and information to farmers is a key hurdle for TC (AATF 2003), and that fostering links with the private sector demonstrated the benefits so that farmers accepted the new technologies (Dubois et al. 2006).

Research by German partners demonstrated the economic potentials of banana TC and the institutional constraints in its dissemination in Kenya (Qaim 1999). High-quality planting material can be delivered via farmer-managed TC nurseries, followed by training in managing TC material. Farmers in Kenya who accepted these TC plants were able to sell bananas and generate income. Improved TC distribution promoted banana processing and reduced imports of bananas and plantains (AATF 2003). However, while TC plants are superior to suckers, their success is dependent on correct management by farmers in the early stages, and farmers require links with markets. Farmer cooperatives can engage the supplier and the users. Farmers who earn more will be able to spend more on planting material.

In Burundi there were private nurseries of TC banana. No new TC nursery was established because the market was already distorted by NGOs buying TC plantlets and giving them away.

Other information sources

More than 500,000 Kenyan farmers adopted commercial micro-propagation of disease-free bananas (Wambugu 2004). A site study in Uganda reported a 36% adoption rate and a high demand for TC banana plantlets (Sonnino et al. 2009). Nine percent of the farmers in Uganda adopted improved TC bananas. There was a high demand for clean planting materials in the lowlands of central Uganda, greatly affected by disease, though farmers receive most material for free from extension agents and government researchers (Smale and Tushemereirwe 2007).

Farmers' multiplication techniques

Most banana growers plant with suckers, from their own gardens or from other farmers' plots. Most Kenyan farmers (90%) plant suckers, but about 25% use TC plantlets (Asoka et al. 2011); some farmers receive TC materials from projects. Since the mid-1990s, the National Banana Research Program of NARO in Uganda has promoted various ways of multiplication (e.g., community mother gardens, planted with disease-free TC banana plantlets; and a farmer receives TC planting materials from NARO, raises it for evaluation, and later gives two plantlets per plant received to another farmer in the community at no cost, who may then sell other plantlets) (Kikulwe et al. 2007).

Through the C3P project (see Chapter 13), clean planting materials were multiplied using macropropagation and distributed to farmers in East and Central Africa. We note, however, that C3P had little influence on the TC project, as the two projects used different models. The TC project promoted clean TC planting materials (of old varieties—not new disease-resistant ones—but virus indexed), not specifically targeting farmers who had been affected by BXW. Whereas C3P was an emergency program to replace planting material for farmers who had been affected by BXW.

In Uganda, women travel long distances looking for planting materials from their relatives or friends to plant before the rainy season starts (Karamu et al. 2004). In Kenya, banana plots are mostly owned by men, who control earnings from the plots, whereas women are involved in marketing (Qaim 1999). According to ISAAA (2007) women controlled 85% of the income from banana sales. Banana TC has allowed women to exert more control over income as the farming system becomes more market-oriented (Wambugu 2004). TC is attractive to women because it reduces risks (Wamue-Ngari and Mwangi 2008). Female-headed and better-educated HH have higher adoption rates of TC banana (Kabunga et al. 2012a). The main reason farmers do not have access to TC banana plantlets is lack of supply.

3.1.2 What changed as a result of the intervention

A cost-benefit analysis based on a survey of 240 farmers in four districts of Uganda by IITA and Makerere University found that production costs and revenues were higher for TC material than for suckers. The banana prices varied greatly between districts and declined sharply with increasing distance from the main market. Production costs for farms far from Kampala city decreased because of lower pest and disease pressure. A farmer who adopted TC and is closer to the city received more profit than one using suckers. But a farmer far from the market earned higher profits from suckers than from TC plants.

In Kenya, much of the population had heard about TC banana, although only a few had had a chance to fully understand its performance and requirements (Kabunga et al. 2012a). Farmers' education, access to agricultural information, knowledge of a nearby TC nursery, and affiliation with groups increased the likelihood of adopting TC. Farmers with access to credit and female-headed HH were more likely to adopt TC plants.

The project established 11 new TC nurseries in Uganda and Kenya. In Uganda, nurseries were run as businesses, independent of the farmers. Most of the nurseries in Kenya were owned by FGs that acted as the customers for these nurseries. In Burundi, farmers owned and managed the nurseries.

3.2 AFFORDABILITY OF THE TC BANANA

Investing in TC provides significant returns, though it requires more capital than conventional bananas (Qaim 1999; Mbogoh et al. 2002). TC provides higher potential yield and income gains for the poorest farmers (Qaim 1999). Mbogoh et al. (ibid.) estimated average costs for establishing a TC banana orchard to be approximately \$3,300/ha in year one, falling to about \$975/ha/year after that, with an estimated profit of about \$515/ha in year one and increasing to \$6,612/ha/year after that. A profit-margin analysis from KARI (Kenya) and Agro-Genetic Technologies (Uganda) for a hardening nursery (with a capacity of 4,000 TC plantlets) revealed a profit margin of 17% (ISAAA 2007). TC banana is profitable for smallholders (Wambuga 2001; Muyanga 2008; Sonnino et al. 2009; Kabunga et al. 2012b; Kikulwe et al. 2012; Lule et al. 2013).

Opportunity costs or trade-offs

Adoption of TC banana depends on the supply of capital and labor. Farmers with little money do not apply enough inputs (e.g., fertilizer), so productivity is low (Muyanga 2008; Kabunga et al. 2012a). Banana orchards can be labor intensive, so off-farm jobs lower the adoption of banana technologies as farmers are busy working elsewhere (Bagamba et al. 2007). The adoption of TC banana in Uganda and TC sweetpotatoes in Zimbabwe depended on the capacity of the promoting agencies to reduce the opportunity costs and risks (Sinnoni et al. 2009). The agencies promoted TC to better-off farmers who could take higher risks. Adoption was stimulated by providing free planting materials, training, and technical support and by buying suckers at subsidized prices from adopting farmers.

Differentiation of information

Two training manuals were written, one for banana TC farmers (about 200 pages) and one for TC nursery operators (about 160 pages). The manual for farmers included lessons on working in groups, growing bananas, business skills, and marketing. The nursery manual covered topics like planning and business skills, managing a nursery, and marketing. The project held 226 training sessions in Uganda for 566 farmers (55% females), 49 sessions in Burundi for 165 farmers (45% females), and 75 sessions in Kenya (202 farmers).

3.3 SEED QUALITY

3.3.1 Before the intervention

At the start of the project, suckers were highly infested with pests and diseases. There were few or no quality standards for banana planting material in the region (Karamura, personal communication). The Seeds and Plant Act (2006) was designed to safeguard the quality of planting materials in Uganda, but even for those few farmers who buy seed, the quality does not match the standards stipulated by the law. Black Sigatoka had reduced banana yields in the region by 30-50% while *Xanthomonas wilt* decimated yields by 80-100% (Tushemereirwe et al. 2003). There were small TC banana enterprises in the region, but they lacked universal quality standards, so farmers did not have full access to the benefits of TC.

3.3.1 What changed as a result of the intervention

TC producers were trained to diagnose banana virus with ELISA and DNA-based indexing. The main banana viruses in East Africa include cucumber mosaic virus, banana bunchy top virus, and BSV. At the end of the intervention, TC banana producers were able to provide uniform and high-quality planting materials. During the project, other efforts were made (meetings, publications, and presentations) to sensitize entrepreneurs, policymakers, and regulators to implement standards and certification for TC banana. Nevertheless, East Africa is still far from implementing a certification scheme for TC banana. Efforts are needed at the higher political levels, because the private sector is not very interested in certification.

In Uganda, several nurseries were implemented by private individuals—mostly smallholder farmers—due to the in-depth training. Because of the project, functional and for-profit nurseries were established in Central Uganda. In Kenya, the concept of farmer-managed nurseries was strengthened. In both countries, as a result of the trainings, 11 new nursery businesses were established or strengthened, and nursery proprietors were able to get higher profits. A cost-benefit analysis of three nurseries in Uganda revealed profits of about \$0.25/plant, with higher profits when more plants were sold. However, in Burundi, despite extensive training of prospective TC banana nursery operators and the project's willingness to build nurseries, no agreement was reached with TC banana producers and buyers. Few, if any, farmers in Burundi were willing to pay for TC banana, which is largely given to them free of charge by the government and NGOs; so there was no demand for group-managed nurseries. In Burundi, the project worked only with FGs.

As a result of this intervention, some FGs were able to secure micro-credit, start TC banana nurseries, and expand into activities beyond banana such as renting event equipment, and outside catering.

During the life of the project, researchers measured the training impact by monitoring the agronomic and economic indicators of 1,350 banana plants in 87 farmers' plots for two crop cycles in Burundi and Uganda. Three groups of randomly selected farmers were monitored: non-TC farmers, untrained TC farmers, and trained TC farmers. Trained farmers harvested twice as much as the others, were able to access better markets, and obtained a higher price per kilogram, which tripled their revenue.

4. Seed producers and seed availability

4.1 THE MODEL

A successful TC satellite nursery model was developed and strengthened in Kenya, and later implemented in Uganda (Figure 12.1). In both countries, the model was sustainable because nursery operators, smallholders, and FGs were able to increase their income. However, production of TC plantlets remains largely unregulated.

TC banana satellite nurseries act as distribution hubs connecting TC producers to farmers, and serve as centers for farmer training and input supply. A sustainable TC banana nursery needs (1) to be close to the TC producer (laboratory) and the market (farmers), and (2) access to water, credit, and a

pickup truck to transport the plantlets. The most successful nurseries were in Kenya, owned by formal FGs whose members also buy the material from the nurseries.

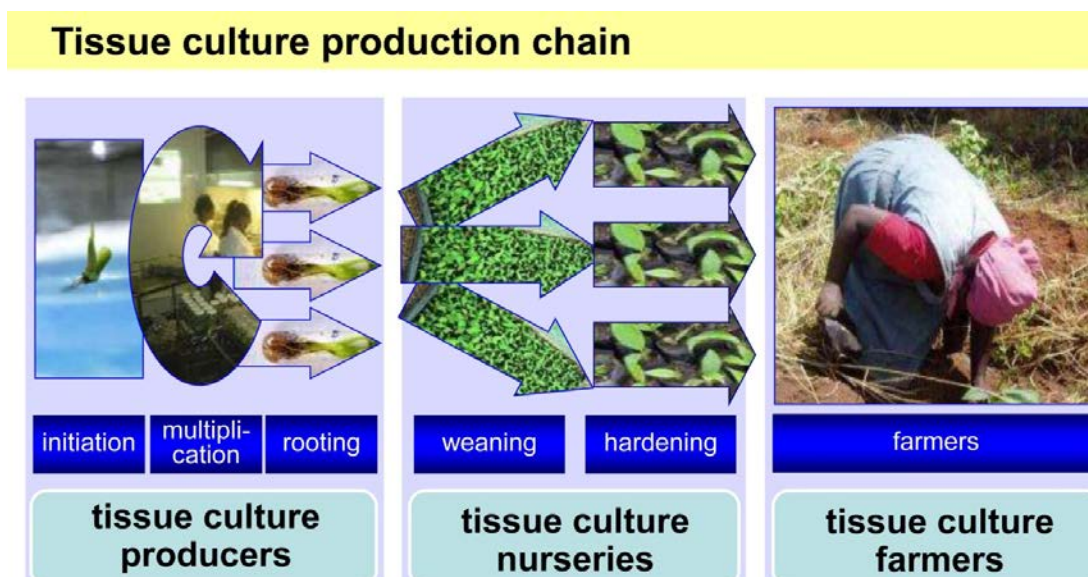


Figure 12.1. TC banana seed system. Source: Dubois et al. n.d.

Scaling up

Plans for scaling up the TC satellite nursery model involved intensive training and distribution of training materials. Several training modules were printed and distributed to extension providers and development organizations. In Uganda, the interveners worked hand in hand with the National Agricultural Advisory Services (NAADS), which was essential for the future of banana TC. In that way the FGs in Uganda were linked to NAADS at the end of the project; NAADS is currently working with them.

Rapid multiplication

This project adapted micro-propagation with TC to produce high-quality planting material for farmers (GTZ 2009). TC banana satellite nurseries were established in strategic locations at a distance from TC production facilities.

Market intelligence

TC plantlets need a lot of care, for which farmer-managed community nurseries were ideally suited, especially in Kenya (AATF 2003; Smith 2004). Nurseries near farmers made it easier to share clean planting material. The community nurseries stimulated farmers to form cooperatives that would allow farmers to access markets, credit, skills, labor, inputs, and tools. These farmers produced high-quality products that conformed to the standards of the market.

It was assumed that there would be sufficient private sector interest in investing in TC, but the private TC laboratories were difficult to include in the project. They were suspicious of outside intervention into quality and certification. Except for the semi-commercial TC laboratory of JKUAT, these producers became less involved over the course of the project, although they were kept abreast of the project findings. The project's work with community nurseries did stimulate demand for TC banana plantlets.

4.2 BENEFITS FOR THE FARMERS

Advantages of the seed

TC seed is often free from pests, including fungi and bacteria. The material can also be free from viruses if it has been properly indexed. TC bananas are true-to-type (they are exactly like their desirable parent), but they grow faster, produce bigger bunches, and flower more uniformly, which makes their harvesting and marketing more predictable. Unlike suckers, TC plantlets can be produced quickly in large quantities.

Disadvantages of the seed

TC plantlets are fragile and need to be hardened before planting, and require appropriate agronomic management when they have been transplanted in the field. Although TC plantlets are pathogen free when they are produced, they are easily infected with pests and diseases if transplanted into infested soils. TC plantlets are more expensive than suckers and generally come in a limited number of varieties. As well, TC has a higher rate of somatic mutations than do suckers (Robinson and Galán Saúco 2010).

4.3 QUALITY ASSURANCE AND REGULATION

Quality assurance mechanisms

The trustworthiness of a nursery operator is important for maintaining quality of planting materials. Most quality aspects can be guaranteed through proper training if nursery operators use good agricultural practices. The project implementers organized hands-on training for TC producers on ELISA and DNA-based indexing, which the participants highly appreciated. Policymakers and regulators were sensitized through meetings, publications, and presentations on how to implement standards and certification for producing TC banana. Uniform, high-quality planting materials were produced, especially in Kenya and Uganda, where the model was sustainable. However, TC bananas are still not certified in East Africa, where the laboratories remain largely unregulated.

New seed regulations

The commercial TC laboratories are supposed to self-regulate the quality and health of their products. Virus certification is urgent, especially as TC plantlets are increasingly traded across borders in Africa. The project communicated several elements that are essential for virus certification in a manual, during training workshops and conferences, and published in peer-reviewed journals (see Section 5.2).

Evaluation of the model

Impact assessments were conducted at the end of the project for Burundi, Kenya, and Uganda. But only the Kenyan data were analyzed (Kabunga et al. 2012a, 2012b, 2014). Education, access to information, and groups and social networks all facilitated the use of TC planting materials.

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

Seed-related policies

Although there are no TC certification schemes in East Africa, there are seed regulations. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) has been supporting the harmonization of seed policies, laws, regulations, and procedures in East and Central Africa (ASARECA 2011). Burundi, Kenya, and Uganda are members on the East African Phytosanitary Information Committee (EAPIC), which was formed to develop country-specific and regional pest reporting methods and internet-accessible databases that support sanitary and phytosanitary requirements (<http://www.eapic.org>).

Each country also had a seed act (or policy draft) in place. Uganda has the Seeds and Plant Act of 2006. The National Seed Certification Service, under the Ministry of Agriculture, Animal Industries and Fisheries (MAAIF), has the mandate of designing, establishing, and enforcing certification standards, methods, and procedures, following OECD guidelines (MAAIF 2006). MAAIF also drafted the National Seed Policy of 2006.

The seed industry in Kenya is governed by the Seeds and Plant Varieties Act (Cap 327) of 1972. Seed regulations were made in 1977 and revised in 1991, incorporating plant breeders' rights. The Act is currently under review to make seed trade fully liberalized and to incorporate harmonized regional seed certification standards (Sikinyi 2010). KEPHIS, established in 1997, is responsible for certifying seed according to the Seeds and Plant Varieties (Seeds) regulations.

In Burundi, the Seed Act of 1999 was revised after the war (Baramburiye 2010). The Seed Production and Control Program, led by the Institut des Sciences Agronomiques du Burundi, started in 2007. The program follows the seed quality control standards set by the East African Countries (ibid.).

5.2 SEED HEALTH AND QUALITY

It is important for the TC producers to sustainably access virus-free and true-to-type mother plants. This could be provided by establishing certified mother plant gardens as a common resource, either by governmental agencies or a consortium of commercial TC producers (Dubois 2011). TC producers have problems with off-types and accidental mixtures of varieties (only observed after planting in the field), resulting in significant quality variations of the TC plantlets, and giving farmers a negative perception of TC. Seed quality standards must involve the private sector and the government in order to be effective.

Seed health and quarantine

This case has no quarantine issues. Six banana and plantain landraces that are tolerant to drought were identified on the islands of Unguja and Pemba, in Tanzania, and maintained at a central site on Unguja. When screened in farmers' fields on Unguja, the varieties responded differently according to the agro-ecological zones. This screening has stopped on Unguja, and the varieties could not be tested in Uganda, Burundi, or Kenya. The quarantine regulations were inhibiting both the import and the export of the test lines with improved disease tolerance.

6. Seed multiplication tools and techniques

TC plantlets are delicate because they have been growing under artificial conditions, dim light, and high humidity. Thus, they have not hardened and can easily lose water when they are exposed to ambient light and temperatures. Having acclimatized in-vitro plantlets saves a lot of labor and materials and increases their survival rates. Such plants can easily be multiplied. The hardened plants can be quickly prepared for the greenhouse nursery. On the other hand, farmers prefer the fully hardened plantlets, ready to be transplanted to the field. This increases the survival rates in the field.

7. Lessons

Accurate information about the nursery operators and smallholder farmers was essential, but was not available in the public domain. Yet, gathering such information was not included in the planning phase of the proposed project.

TC banana laboratories, largely in the private sector, were difficult to include in the project. These producers were suspicious of outside intervention into quality and certification, and most of their customers were large government organizations and NGOs, dedicated bulk-buyers of TC banana plantlets. Some labs dropped out of the project. But focusing on nurseries and FGs helped to increase the market mix and increased the demand for TC banana.

The project implementers (research organizations and development partners) found it hard to engage with policymakers, particularly those concerned with quarantine and plant health.

Training events need to be tailored to specific situations. Training in Burundi was quite basic, whereas in Kenya farmers were introduced to new methods of compost making, solar



Artificial conditions. TC bananas growing in vitro.
Photo by Jeff Bentley

ripeners, and bookkeeping on computer spreadsheets. Training involved more than just how to grow TC bananas; the business plans developed for the TC nursery operators were useful for establishing nurseries and similar businesses. About 70% of the TC farmers in Uganda stayed in the training, even though the schedule was intense.

Planning with nursery operators and farmers needed to take their needs into account. Some FGs, for instance, were not interested in being trained in marketing. Initially, the large demonstration gardens were meant to be used as training tools and as marketing tools for the TC nurseries. In Uganda, some of the banana TC demonstration gardens were poorly managed or even abandoned. Demonstration gardens should have been planted after the training to ensure proper management of TC banana planting materials.

References cited

- ASARECA. 2011. Impacts of an improved seed policy environment in Eastern and Central Africa. (Available from www.asareca.org/resources/reports/Impactsofanimprovedseedpolicyenvironment.pdf)
- Baramburiye J. 2010. Baseline seed study for Burundi Harmonization of seed policies, laws and regulations. (Available from <http://afsta.org/wp-content/uploads/documents/BURINDI%20SEED%20SECTOR%20BASELINE%20STUDY.pdf>)
- Carter BA, Reeder R, Mgenzi SR, Kinyua ZM, Mbaka JN, Doyle K, Nakato V, Mwangi M, Beed F, Aritua V, Lewis Ivey ML, Miller SA, Smith JJ. 2010. Identification of *Xanthomonas vasicola* (formerly *X. campestris* pv. *musacearum*), causative organism of banana xanthomonas wilt, in Tanzania, Kenya and Burundi. *Plant Pathology* 59(2):403.
- Dubois T. 2011. Towards a healthy banana TC industry. R4D Review Issue 6. (Available from <http://r4dreview.org/2011/04/towards-a-healthy-banana-tc-industry/>)
- Dubois T, Coyne TD, Kahangi E, Turoop L, Nsubuga EWN. 2006. Endophyte-enhanced banana tissue-culture: echnology transfer through public-private partnerships in Kenya and Uganda. *ATDF Journal* 3:18–24.
- Dubois T, Dusabe Y, Lule M, Van Asten P, Coyne D, Hobayo JC, Nkurunziza C, Ouma E, Bauer V, Hoffman V, Kabunga N, Qaim M, Kahangi E, Mwirigi P, Kisii D. n.d. Tissue culture banana for smallholder farmers: lessons learnt from East Africa. (Available from http://www.promusa.org/tiki-download_file.php?fileId=805)
- GTZ. 2009. Banana tissue culture: Community dissemination pathways for delivery of high quality planting material to create markets for African farmers. Bonn: GTZ (Deutsche Gesellschaft für technische Zusammenarbeit). Fact sheet. 2 pp.
- Jagwe J, Ouma E, van Asten P, Abele S. 2008. Banana Marketing in Rwanda, Burundi and South Kivu. CIALCA Project Survey Report. (Available from http://www.cialca.org/files/files/Banana_market_report.pdf on 14.02.2014)

- Kabungu NS, Dubois T, Qaim M. 2012a. Heterogeneous information exposure and technology adoption: the case of tissue culture bananas in Kenya. *Agricultural Economics* 43:473–485.
- Kabungu NS, Dubois T, Qaim M. 2012b. Yield effects of tissue culture bananas in Kenya: Accounting for selection bias and the role of complementary inputs. *Journal of Agricultural Economics* 63(2):444–464.
- Kabungu NS, Dubois T, Qaim M. 2014. Impact of tissue culture banana technology on farm household income and food security in Kenya. *Food Policy* 45:25–34.
- Kalyebara R, Wood S, Abodi PN. 2007. Assessing the potential impact of selected technologies on the banana industry in Uganda. In: Smale M, Tushemereirwe W, eds. *An Economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania*. IFPRI Research Report. Washington, DC. p. 141–153. (Available from <http://www.ifpri.org/sites/default/files/publications/rr155.pdf>)
- Karamura D, Mgenzi B, Karamura E, Sharrock S. 2004. Exploiting indigenous knowledge for the management and maintenance of Musa biodiversity on farm. *African Crop Science Journal* 12:67–74.
- Lule M, Dubois T, Coyne D, Kisitu D, Kamusiime H, Bbemba J. 2013. *Trainer’s manual. A Training Course for Banana Farmers Interested in Growing Tissue Culture Bananas*. Ibadan: IITA. 126 pp.
- MAAIF. 2006. *The National Seed Policy. 1st Draft*. 20 pp.
- Mbaka JN, Nakato VG, Auma J, Odero B. 2009. Status of banana Xanthomonas wilt in western Kenya and factors enhancing its spread. *African Crop Science Conference Proceedings* 9:673–676.
- Njuguna J, Nguthi F, Wepukhulu S, Wambugu F, Gitau D, Karuoya M, Karamura D. 2010. Introduction and evaluation of improved banana cultivars for agronomic and yield characteristics in Kenya. *African Crop Science Journal* 16(1):35–40.
- Qaim M. 1999. *Assessing the Impact of Banana Biotechnology in Kenya*. ISAAA Briefs No. 10. ISAAA: Ithaca, NY. 48 pp.
- Rishirumuhirwa T, Roose E. 1998. The contribution of banana farming systems to sustainable land use in Burundi. *Advances in GeoEcology* 31:1197–1204.
- Robinson JC, Galán Saúco V. 2010. *Bananas and plantains. Crop Production Science in Horticulture*. Wallingford: CABI. 297 pp.
- Sikinyi EO. 2010. *Baseline Study/Survey Report on the Seed Sector in Kenya*. Seed Trade Association of Kenya. (Available from <http://afsta.org/wp-content/uploads/documents/KENYA%20SEED%20SECTOR%20BASELINE%20STUDY.pdf>) (Accessed on 3 November 2014)
- Smale M, Tushemereirwe W, eds. 2007. *An Economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania*. IFPRI Research Report. Washington, DC. (Available from www.ifpri.org/sites/default/files/publications/rr155.pdf)

- Sonnino A, Dhlamini Z, Mayer-Tasch L, Santucci FM. 2009. Assessing the socio-economic impacts of non-transgenic biotechnologies in developing countries: The case of plant micropropagation in Africa. Rome: FAO.
- Tushemereirwe W, Kangire A, Smith J, Ssesiwoko F, Nakyanzi M, Kataama D, Musiitwa C, Karyeija R. 2003. An outbreak of bacterial wilt on banana in Uganda. *InfoMusa* 12:6–8.
- Vershelde M, D’Haese M, Rayp G, Vandamme E. 2011. Challenging small-scale farming, a non-parametric analysis of the (inverse) relationship between farm productivity and farm size in Burundi. Working Paper. Faculteit Economie en Bedrijfskunde, Universiteit Gent, 28 pp.
- Vézina A, Dubois T. 2015. Planting material. Promusa. (Available from <http://www.promusa.org/tiki-index.php?page=Planting+material>)
- Wambugu F. 2004. Food, Nutrition and economic empowerment: The case for scaling up the Tissue Culture Banana Project to the rest of Africa. Paper presented at the NEPAD/IGAD regional conference: Agricultural Successes in the Greater Horn of Africa held in Nairobi, 22–25 November 2004.

CHAPTER 13

An emergency banana disease in East Africa

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Abstract

The Crop Crisis Control Project (C3P) worked in six East African countries (Uganda, Burundi, DR Congo, Kenya, Rwanda, and Tanzania) to stem the advance of BXW, a bacterial disease of banana that emerged after 2001. Bananas and plantains were (and still are) important commercial and food security crops in the region. All local banana and plantain varieties were susceptible to BXW. The project implementers and donors thought of the disease as an emergency. In response, the project proposed what seemed like an appropriate technology to clean planting material: macropropagation (to distinguish it from its rival, TC, which is micropropagation). To macropropagate a banana plant, the farmer takes a healthy banana corm, strips away the outer leaf sheaths, destroys the primary sprout, and then plants the corm in sterile, humid sawdust in a shaded nursery, after which axillary buds will sprout. Many farmers were taught the importance of using clean planting material, but macropropagation was too time-consuming and labor-intensive to meet all of the farmer demand for seed bananas. After the project ended, researchers (who were paying attention to farmers) learned of easier ways to manage BXW. Farmers observed that a wilting banana plant still produced at least some healthy suckers, which could be used as planting material. Suckers that looked healthy probably were healthy, and could be planted, eliminating the need for tedious macropropagation.

Rationale

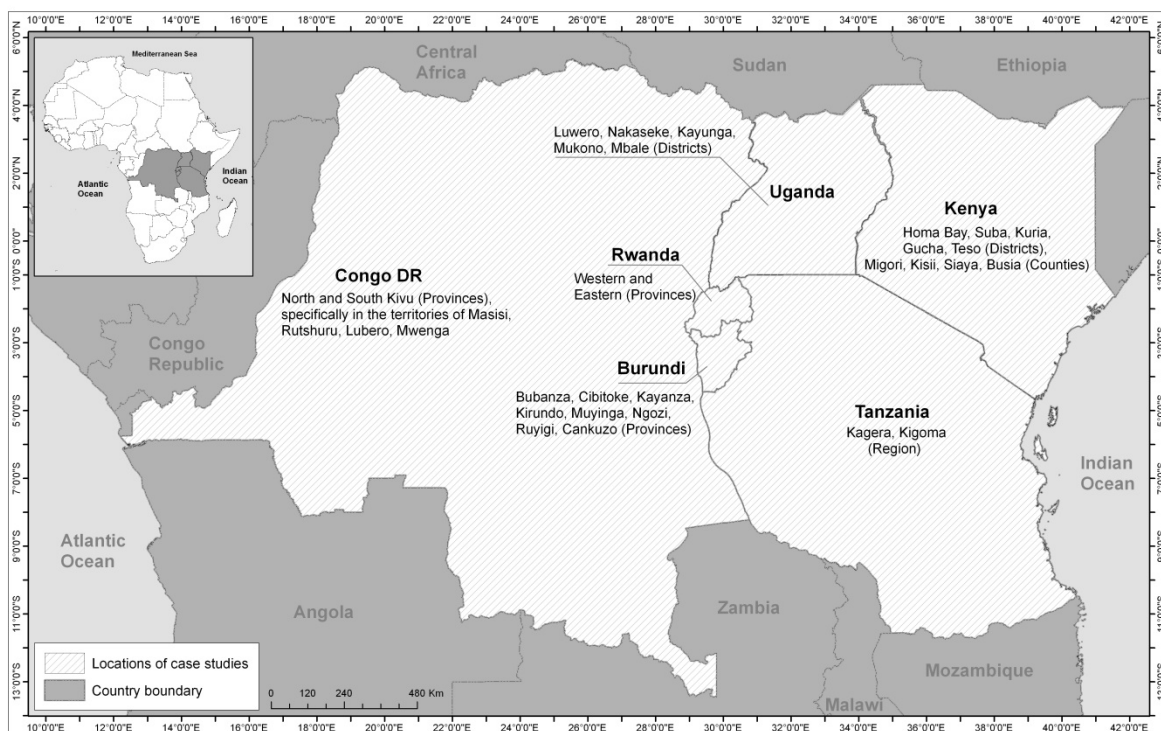
In the 1960s, BXW was discovered on enset in Ethiopia; by 2001 the disease had spread to Uganda, and would soon reach other East African countries. All local varieties of banana and plantain were susceptible to BXW. Plant pathologists were especially alarmed, because there was no effective control of BXW. The project proposed to create and distribute clean planting material, using macropropagation, which is cheaper and easier than TC. The varieties that were cleaned were still susceptible to the disease.

1. The intervention

Musa spp. (bananas and plantains) play a vital role in the food security and HH income in East and Central Africa. The BXW epidemic, caused by the bacteria *Xanthomonas musacearum* pv. *campestris*, has posed a serious threat to East and Central African bananas since 2001 (Karamura and Johnson 2010). BXW is usually carried by insect vectors (Tinzaara et al. 2006), contaminated tools, and infected planting materials (Eden-Green 2004). Hence, part of the strategy to combat it is to destroy infected plants and, after a fallow or rotation period, to replant with clean materials.

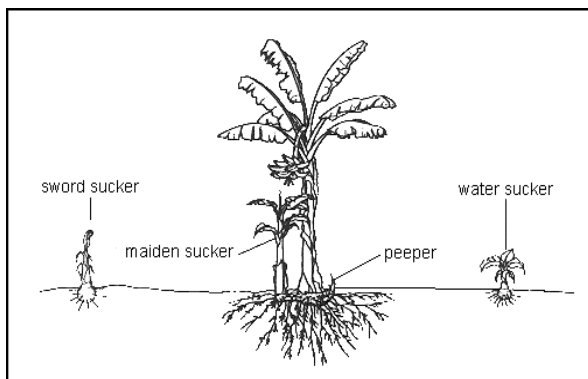
In 2006, the six-country C3P was launched under the auspices of ASARECA and Common Market for Eastern and Southern Africa. Led by CRS and IITA, the \$4.5 million initiative mobilized more than 40 partners to combat two diseases of staple food crops, CMD and BXW, in East and Central Africa (Eden-Green 2008; the project website: <http://c3project.iita.org>). This case study only examines activities with BXW.

C3P was funded by USAID's Famine Relief Fund and was administered through REDSO/Nairobi. The program had two objectives—namely that: (1) regional stakeholders institutionalize coordinated agricultural disaster response mechanisms and (2) farmers employ effective measures to control CMD and BXW. The 24-month regional project ended in April 2008 (*ibid.*).



The technology chosen for multiplying planting materials during C3P was macropropagation, in combination with mother gardens. Macropropagation is a method of multiplying bananas by sprouting multiple shoots from corm buds. It can be a village-level technology in which selected corms are harvested, pared, heat-treated, and placed in a sterile medium in shaded humidity chambers to allow shoot development. Macropropagation activates latent buds by destroying the apical dominance (killing the main shoot with a knife). Buds are incised to encourage multiple shooting. Shoots are detached, rooted, and hardened before field planting (see Figure 13.1). This technique can provide replacement

plants where disease has reduced plantation life, or multiply newly introduced varieties for distribution (CIALCA 2008).



Where to find your sucker.
Drawing from Swennen and Ortiz (1997).



The corms from the suckers are uprooted, pared, and heat-treated.

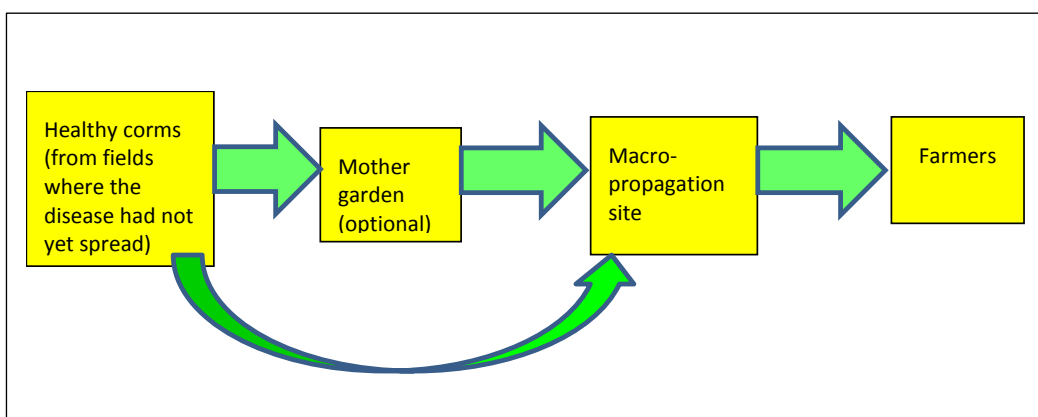


Figure 13.1. Distribution model of clean planting material.

Theory of change

Demand for planting material was clear at the outset of the project (Eden-Green 2008). Given the plant health crisis, the quality of local seed could not meet these demands. This called for a large-scale multiplication of clean planting materials.



Heat-treated corms placed into the macropropagator.
Photo by S. Walsh



Hardening the banana plantlets from the macropropagator.
Photo by S. Walsh

Scaling up

The project was deemed a success. C3P's main objectives were rehabilitation, raising awareness, and training of farmers in BXW areas. At the end of C3P, disease incidence and management competencies were evaluated on 96 randomly selected, representative farms that had been exposed to *Xanthomonas* wilt training and messages in the six countries. Competencies doubled, and those applying the recommendations significantly reduced disease incidence. An estimated 51,000 farmers in target benchmark sites (or 62,000 ha) tripled their yields and the rate of reported disease outbreaks declined by 20–40% (Karamura 2008). In all countries, functional nurseries were producing plantlets by the end of the project. However, late implementation of macropropagation in most countries, and a lack of planning for sustainability of the nurseries, reduced the impact of the intervention (Eden-Green 2008).

Framework: Banana wilt in East Africa

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability/ profitability issues	Info to create awareness & demand		
Policy-makers					Allowed the project to continue	
National research		Favored eradication of diseased plants, replanting				
International research	IITA & CRS project	Got suckers from disease- free areas	Macropropa- gation was slow		Susceptible, commercial varieties	The technology had problems
Traders (local markets)	Not involved					
Private seed sector	Not involved					
Farmer organiza- tions		Propagation sited in communities	A technique too tedious for farmers			Farmers found other ways to get healthy seed
NGOs	CRS was a key partner	40 organizations involved				
Private sector processors				Keen market demand for the fruit		
Seed users			May have been little impacted			

2. General context

Farming systems

Smallholder banana systems were described in the previous chapter on Banana TC.

CP3 was carried out in the following locations:

Uganda: Luwero, Nakaseke, Kayunga, and Mukono in Central Uganda, and Mbale in Eastern Uganda

Burundi: Bubanza, Cibitoke, Kayanza, Kirundo, Muyinga, Ngozi, Ruyigi, and Cankuzo Province

DR Congo: North and South Kivu provinces, specifically in the territories of Masisi, Rutshuru, Lubero, and Mwenga

Kenya: Homa Bay, Suba, Migori, Kuria, Gucha, Kisii, Siaya, Bondo, Teso, and Busia

Rwanda: Western Province (Kanama, Cyanzarwe, Gisenyi ville, and Nyamyumba) and Eastern Province (Ngoma, Kirehe, and Kayonza)

Tanzania: Kagera (Bukoba, Muleba, Biharamulo, Ngara, and Karagwe) and Kigoma (Kibondo, Kasulu, and Kigoma) regions.

Market importance of bananas and plantains for farmers

Bananas are a major contributor to food and income security in East and Central Africa. All types of bananas are exported, although the cooking and the beer types dominate the trade (Jagwe et al. 2008).

In **Uganda**, bananas are crucial for the economy and food security. Grown by about 75% of the farmers on 38% of Uganda's arable land, banana is a staple to an estimated 10 million Ugandans, with an annual production in 2006 of 10 MT (NARO 2006, cited in Karamura 2011).

In **Tanzania**, women's participation in sales of cooking bananas is declining but still substantial. As bananas become more important in the market, more men are getting involved, especially with brewing varieties (Edmeades et al. 2007).

In **Rwanda**, 80% of rural HH get more cash from bananas than from coffee or any other crop, and for 41% of HH, bananas are a more important source of cash than all other crops combined (Verwimp 2002). Beer banana is a particularly important source of income (since the same HH can grow the bananas and brew the beer).

In **DR Congo**, banana products (juice, wine, bunches, and fibers) are consumed and marketed locally. This generates income that circulates mostly at village level (Sebasigari 1987; Jagwe et al. 2008).

General seed sector characteristics

Musa plants are vegetatively propagated through lateral shoots, or "suckers," originating from the corm (the true underground stem of the mother plant). The suckers emerge from the soil as soon as they are clear of the mother plant, forming mats or clumps of stems around a single plant.

Farmers will usually detach a sucker from the mother plant when planting new fields or expanding a plantation. Outside of technology transfer projects, there are no reports of widespread use of multiplication technologies by small-scale farmers in Africa (Jacobsen 2013).

Trends, developments, ongoing change

BXW arrived at the start of the new millennium and, by 2004, entire crop holdings had been wiped out in areas where highly susceptible banana varieties were common.

In many regions of East and Central Africa, the expansion of supermarkets has created demand for high-value agricultural products, including bananas. Vegetable producers in supermarket channels in Kenya increased average HH income by 48%, with smaller and poorer farms benefitting over-proportionally (Rao and Qaim 2011).

Banana production in Rwanda has fallen by over 40% over the past two decades due to increasing pest and disease pressure, including BXW since 2005 (Nsabimana et al. 2008). In 2006, the total area affected by BXW was estimated at 433 ha, and associated yield loss estimates were almost \$650,000.

Farmers in DR Congo, particularly the North and South Kivu regions, have undergone years of upheaval and continue to face significant humanitarian challenges. During the life of C3P, the three provinces (North Kivu, South Kivu, and Maniema) were considered “post-conflict” zones, yet there was still much displacement and killing in the region (S. Walsh, pers. comm.). Even in the absence of conflict, however, river transportation is slow throughout DR Congo, roads are poorly maintained, and vehicles are mostly old and subject to breakdown (Mobambo et al. 2010). This makes it challenging to develop a profitable market for bananas and plantains

3.1 Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

What the interveners knew

The C3P project mapped the geographic extent of the BXW epidemic, so it was not possible at the start of the project to estimate how many plants would be uprooted. Therefore it was not known how many plants had to be propagated. So in smallholder communities, C3P started with awareness raising, training, and disease recognition. It was clear from the start that planting material would be in high demand, but the priority was to control the spread of BXW and to start recovery from the disease (S. Walsh, pers. comm.).

Farmer representatives expressed a massive demand for banana planting materials following destruction of their diseased plants. In response, governments and NGO partners submitted country proposals, which were backed up by technical support from IITA and regional training provided by Bioversity International. The country proposals included developing sources of clean planting materials (of susceptible banana varieties) using macropropagators, mother gardens, and related farmer-accessible methods (Eden-Green 2008).

The proposal stated that 180,000 suckers would be produced. More than five extensionists and 20 farmers would be trained in macropropagation in each targeted district in Uganda; 20 extensionists and 100 farmers would be trained in each of the other five countries. At least 10 macropropagation units would be established in each targeted district in Uganda, and 10 units in each of the other five countries.

Other information

Survey data gathered during C3P gradually demonstrated the true extent of the need for planting material. For example, in Rwanda alone, a 2007 survey estimated that up to 800 ha were affected by BXW. In collaboration with the World Food Program, C3P instituted the Food For Work scheme, and 329.7 ha of banana plantations, more than 500,000 plants, were systematically uprooted (Karamura 2008; Eden-Green 2008). The original target number of macropropagated plantlets for Rwanda, however, was only 11,820. In July 2008 (after completion of the 2-year C3P project), an evaluation of the

project reported that not a single replacement plant had been provided in Rwanda, with 4,600 plantlets still stuck in the macropropagators (Eden-Green 2008).

The production of large quantities of high-quality, clean planting material takes a long time. Producing 50,000 plants takes an estimated 10–44 months, depending on the method chosen (Staver and Lescot 2013). The use of macropropagation is not the most rapid (28 months for 50,000 plants), but it has a few advantages:

- 1) It can accommodate a diversity of varieties
- 2) It is relatively low-cost
- 3) Farmers can manage it.

There have been previous *Musa* seed system interventions. Before C3P, in 1995, the National Banana Research Program of Uganda started multiplying banana by TC in collaboration with IITA. They also multiplied elite varieties for farmers via mother gardens and direct distribution.

In **Tanzania**, the 5-year project (1998–2003) entitled “Propagation and Diffusion of Superior Banana Cultivars,” which was launched by the Kagera Community Development Program (KCDP) in collaboration with the Belgian Technical Cooperation, the Catholic University of Leuven, and Tanzanian authorities. The project disseminated superior banana varieties and included the use of TC and farmer-managed multiplication plots (Kikulwe et al. 2007). Initially, 71,000 TC banana plantlets were imported into the Kagera region and hardened at Kyakairabwa nursery (mother garden) near Bukoba Town. KCDP involved NGOs, primary schools, district departments of agriculture, and some individual progressive farmers in establishing nurseries and multiplying bananas. Because KCDP supplied farmyard manure and paid laborers, multiplication of these bananas was successful and proceeded rapidly. KCDP distributed an estimated 1 million suckers via direct (nursery-to-farmer) and indirect (farmer-to-farmer) diffusion (ibid.).

3.1.2 What changed as a result of the intervention

C3P consolidated the need for clean planting material through training and awareness raising. The project aimed to train 6,000 farmers in total; it effectively trained 64,514. Training may have transmitted the knowledge, but it is possible that infected planting materials were still used. Farm competencies gained through training were high (60–100%) for disease symptoms and control measures, but farmers could not explain the various mechanisms that spread disease (Karamura 2008).

Macropropagation activities per country are listed below (Eden-Green 2008):

In **Uganda**, targets for plant production in C3P macropropagators and mother gardens were achieved or exceeded, and facilities were managed by farmer or community groups at the end of C3P. At least one local authority (in Mbale district, Eastern Uganda) had committed funds to build more macropropagators to serve additional communities.

In **Tanzania**, one macropropagation unit was still in the hands of MARDI at the end of C3P. Initial plantlets were used to establish a mother garden, also under MARDI management, and some plantlets were being distributed to farmers or sold to the authorities, including a local prison.

In **DR Congo**, macropropagators were operational and successful in the target areas, with plans to establish mother gardens in local task force farmers' fields. There was concern about funding at the end of the project; at one location the nursery was abandoned due to security issues.

In **Rwanda**, macropropagation only started in September 2007 due to delays with mother corms. Some produced poorly (because of the cool climate) and were soon abandoned. At the end of the project no plantlets had been produced.

There was no information on macropropagation in Burundi and Kenya in the evaluation report (Eden-Green 2008).

There were concerns about the sustainability of the macropropagation after the end of C3P. There was, for example, a stark contrast between the successful activities in Goma (DR Congo) compared with those of neighboring Rubavu (Rwanda), where macropropagation had stalled by the end of the project (ibid.). Eldad Karamura reports that macropropagation is now good business in Central Uganda due, at least in part, to the dominance of the 'Kayinja' varieties in this region. 'Kayinja' has a 3- to 5-year crop cycle, whereas East African Highland AAA bananas are perennial.

3.2 AFFORDABILITY OF THE MACROPROPAGATED BANANAS

Because of the disease epidemic, plantlets were donated to farmers at all macropropagation sites. In Uganda, farmers were promised free planting materials of cassava, beans, and bananas in exchange for eradication of diseased bananas. C3P mobilized community action and ownership, yet the 2-year project was too short to multiply and replant the banana plants (Eden-Green 2008). It is unclear whether the propagation chambers provided a suitable solution in the longer term.

Opportunity costs or trade-offs

The additional labor costs of the macropropagation nurseries require consideration.

3.3 SEED QUALITY

Before the intervention

BXW in Rwanda caused an estimated annual yield loss of 9,231 t, worth more than \$1,200,000 (Karamura 2008). A survey in the Bwera region (DR Congo) indicated that the BXW outbreak lowered yields from 20 t/ha/year to almost zero, with income losses of about \$1,600/ha/year (Vigheri and Lubanga 2006). In Uganda in 2005, the country lost an estimated \$35 million worth of bananas. The estimated loss in Tanzania as of April 2006 was more than \$350,000 (AATF 2009).

During C3P, most farmers were unaware that their bananas were wilting because of bacteria. Farmers had no management options and did not know that planting with suckers would spread BXW. The epidemic spread so quickly and so far that researchers struggled to identify management options, particularly for smallholders. C3P assumed that the project had to create an entirely new seed system.

What changed as a result of the intervention

Plants produced in the macropropagators or in mother gardens, following proper management guidelines, are free of BXW; however, the plantlets remain susceptible to reinfection.

During C3P in Uganda, corms for the macropropagation chambers were sourced from farms in southwest Uganda, which were free of BXW. Access to clean planting materials was a problem during C3P, and there were concerns that macropropagation might disseminate banana viruses unless origins and health status of starting materials were monitored and controlled (E. Karamura, pers. comm.; Eden-Green 2008).

The project advised the complete uprooting of diseased mats and burning or burying plant debris, and using clean tools and the early removal of male buds to discourage insect vectors. Such activity is conceivable in a commercial plantation, but it requires proportionately much more effort on small farms. After the project ended, researchers discovered that *Xanthomonas* bacteria do not colonize all lateral shoots. This knowledge allowed novel control methods to be developed, in which only the visibly diseased plants within a mat are removed. This greatly reduced the number of destroyed plants at farm level (Ocimati et al. 2012; Blomme et al. 2014).

In the years after C3P, studies examined incubation periods and latent infection in asymptomatic plants. Field observations and reports from farmers indicated that plants continue to grow, and were visibly healthy, even after removal of a pseudostem with advanced inflorescence symptoms.

This suggests that it is possible to stop bacteria from reaching the corm and crossing to the lateral suckers by removing the pseudostems of those plants with wilting male bracts (Ocimati et al. 2012).

It is unfortunate that this information came to light only after the project ended—it would have been useful to know. But then, there is a steep learning curve during an emergency. The ability of the plants to withstand the disease suggests that the management requirements of BXW were not as drastic as the plant pathologists originally thought (although the farmers urgently needed information about *Xanthomonas*).

4. Seed producers and seed availability

4.1 THE MODEL

The aim of macropropagation was to provide a technology that farmers could manage themselves. Macropropagation was a novel technology, producing unfamiliar planting materials (plantlets). Mother gardens, by contrast, are more familiar to farmers, serving both as a source of clean planting materials (traditional suckers) and as a demonstration of good management practices under threat of BXW.

As an emergency seed system intervention, C3P evaluated its challenges and measured its successes by its ability to address the emergency of the BXW epidemic. Yet macropropagation and mother gardens had not previously been used in an emergency situation. The few seed system interventions that might have served as precedents to C3P in Cameroon and Nigeria had many shortcomings.

New seed model

C3P used the model of “Macropropagation coupled with mother gardens.” These sites were managed by individual farmers or by groups, usually supported by an NGO. Some of these gardens had previously been demonstration plots.

Key criteria for success identified during the project included the good integration between NGOs and NARS, and targeting women (where they were the main producers). The most successful strategy was focusing on productive trainees and dynamic communities where a sense of ownership was created.

Scaling up

After C3P, CIALCA continued macropropagation in Rwanda, Burundi, and DR Congo. By the end of 2009, nearly 80 trainers (60% from NGOs) had received CIALCA training on macropropagation and were to scale out these activities in other sites. In Rwanda, by the end of 2009, six farmer cooperatives were already using macropropagation and another 11 had expressed interest. Constraints cited by nursery owners included the lack of training, lack of a market for the plantlets, high labor costs, and the price of materials used for the nurseries (Ouma et al. 2011). Options for producing planting materials may not have been thoroughly discussed before starting the project.

Farmers were probably the first to learn that they could find clean planting material simply by looking for symptom-free suckers. It took the researchers a little longer, with their randomized field trials. This is probably one reason that the farmers were uninterested in the macropropagated plantlets, which are unfamiliar and fragile.

The C3P case suggests that scaling out would require:

- More attention to the whole value chain in order for the nurseries to be sustainable
- Cost-benefit analyses, including opportunity costs, to determine pricing margins and business feasibility
- Examination of off-season uses of the macropropagation unit
- Sufficient healthy corm material (ideally via mother gardens and multiplication plots)
- Transport
- Water
- A practical QDS certification procedure.

Rapid multiplication techniques

Macropropagation was well adapted to this situation because it is low cost and farmer-friendly. Another RMT, used only sporadically during the C3P intervention, includes growing suckers in a multiplication plot, whereby just before flower emergence, plants are decapitated to stop further flower or bunch development and stimulate sprouting of abundant suckers.

Such a plot could be coupled with nurseries for microcorms, which are small, cone-shaped suckers of 200–300 g, which are detached from the mother plant, pared and treated with a surface disinfectant, and then planted into small nursery bags filled with clean substrate (Staver and Lescot 2013).

Recent studies suggest that symptomless suckers from heavily diseased fields (i.e., incidence >70%) may be used as planting material, especially by communities lacking access to clean planting materials (Sivirihauma et al. forthcoming).

Market intelligence

At the start of C3P, TC was reviewed and rejected as too expensive (\$1/plantlet), considering the massive demand for planting materials. The TC project (see previous chapter) subsidized the production of plantlets, so the business model may not be sustainable without a project. The TC project also included a lot of value chain and market training, which was not feasible in C3P.

4.2 BENEFITS FOR THE FARMERS

Advantages of macropropagation

Assuming 100% good management practices, macropropagated plantlets should be free of pests and diseases. They are cheaper than TC, and are less bulky and more abundant than suckers.

Disadvantages of macropropagation

Macropropagated plantlets are more fragile than suckers. With a smaller, more fragile root system, smaller corm, and several young leaves, they are more vulnerable to drought. It is essential that they receive sufficient water in the first few months after planting.

They are more susceptible to damage during transport. Transport of macropropagated plantlets is challenging, and nurseries should be located near the farmers' fields.

Screening the initial corm material in the propagators is essential to produce healthy plantlets. Macropropagation can propagate various diseases if the corms are not sourced from disease-free regions or TC.

Macropropagated plants are not resistant to pests and diseases, and thus good plantation management is key to realizing all potential benefits.

4.3 ON QUALITY INSURANCE AND REGULATION

The quality of the planting material depends on the nursery holder. Quality can be guaranteed through proper training and good management. Corms used for propagation should be pared, treated with a fungicide, and dried in the shade for a day before planting in the nursery. If important bacterial, fungal, or viral diseases are present in the region, corms should ideally be sourced from certified TC labs.

Eden-Green (2008) and Eldad Karamura (pers. comm.) raised concerns about the health of the corms used in the propagation units. Corms were screened for BXW but not for other diseases, such as viruses.

Evaluation of the model

The project was evaluated by Eden-Green (ibid.) and Karamura (2008); there are also many reports and peer-reviewed articles. However, the seed systems model used during C3P was not evaluated in detail, because the main goals of the project were aimed at rehabilitation, awareness raising, and training of farmers in the areas affected and threatened by BXW.

5. Regulation and policy affecting farmers' use of quality seed

Most of the countries (except DR Congo) involved in C3P belong to EAPIC. EAPIC's website (<http://www.eapic.org>) refers to such international protocols and standards as the International Standards for Phytosanitary Measures and the International Plant Protection Convention protocol (WTO Agreements). EAPIC's five priority crops comprise banana, maize, cassava, rice, and beans. EAPIC may affect the development of regional seed system networks through their efforts to promote pest surveillance technologies, pest information management systems, and enhanced regional collaborations.

ASARECA is a subregional, not-for-profit association established in 1994 by 10 member countries: Burundi, DR Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, Sudan, Tanzania, and Uganda (<http://www.asareca.org>).

Under the auspices of ASARECA is the Banana Research Network for Eastern and Southern Africa. The network seeks to increase the contribution of bananas to food security and economic growth in East and Central Africa, and to contribute to increased agricultural productivity in the region in order to establish a sustainable, commercial banana sector. The network is part of the ASARECA Staples Crop Program.

In September 1999, ASARECA, through support from a USAID-funded project undertaken by ECAPAPA, found that there is need to harmonize seed policies and regulations in ASARECA member countries. Differences in regulations and procedures for seed certification constrain germplasm exchange and need to be addressed. There is a general lack of a regional policy framework to share clean materials and improved varieties across countries.

Harmonization and enforcement of regional regulations could benefit macropropagation nurseries and farmers. Nurseries producing certified planting materials would be a step toward preventing regional disease outbreaks. Yet a grass-roots technology such as macropropagation probably does not need the level of scrutiny associated with certification. More informal QDS protocols might be good enough.

In the face of emerging diseases, such as BXW, quality standards need to be imposed by plant health authorities through extension services, NGOs, and NARS. Having a list of nurseries would ease communication in the event of an epidemic. C3P had a list of nurseries directly related to the project (while it was operating), but there is not a complete, up-to-date list of nurseries and other sources of planting material (from C3P, FGs, other projects, etc.).

6. Seed multiplication tools and techniques

The costs for building a macropropagation chamber and using it for a year in Africa varies from \$100 to over \$5,000 (Danso et al. 1999; Njukwe et al. 2007; Ouma et al. 2011). But this is less than TC—a modest TC facility can cost \$50,000 to equip (Arias et al. 2003). As businesses, macropropagation nurseries are hampered by the amount of initial investment required.

Providing clean corms was a particular constraint during C3P. In Uganda, for example, corms originating in certified TC labs would have been the preferred material. Instead, corms were sourced from known uninfected farms in southwest Uganda.

During C3P there was no cost-benefit analysis of macropropagation for smallholders in East and Central Africa. In 2010, an economic analysis of banana seed systems using macropropagation in Rwanda, Burundi, and Eastern DR Congo demonstrated that 47–77% of the chambers operated at a loss. Most institutions were producing banana plantlets to give to farmers for free, with donor support. Suppliers of *Musa* plantlets in Central Africa cited problems with construction, maintenance, lack of market opportunities, and technical problems (Ouma et al. 2011).

7. Lessons

The evaluation by Eden-Green (2008) draws two main lessons from macropropagation:

It was almost 15 months into the 2-year project before macropropagation was started in any country outside Uganda. This allowed insufficient time to scale up production and dissemination of planting materials.

Sustainability was not thoroughly considered. In the rush to provide bacteria-free seed, the project could have easily disseminated virus-laden material throughout the region. That seems not to have happened, partly out of luck.

In retrospect, starting macropropagation at the earliest date would have been preferable, especially considering the time required to produce *Musa* planting materials. It is not entirely clear from the documentation how many nurseries were effectively set up in each country or how productive they were. Local communities might have welcomed more nurseries, even ones that did not outlive the project.

References cited

- AATF. 2009. Feasibility Study on Technologies for Improving Banana for Resistance against Bacterial Wilt in Sub-Saharan Africa. Nairobi: African Agricultural Technology Foundation. 102 pp.
- Arias P, Dankers C, Liu P, Pilkauskas P. 2003. The World Banana Economy 1985–2002. Rome: FAO, 86 pp.
- Blomme G, Jacobsen K, Ocimati W, Beed F, Ntamwira J, Sivirihauma C, Ssekiwoko F, Nakato V, Kubiriba J, Tripathi L, Tinzaara W, Mbolela F, Lutete L, Karamura E. 2014. Fine-tuning banana *Xanthomonas* wilt control options over the past decade in East and Central Africa. *European Journal of Plant Pathology* 139(2):271–287.

- CIALCA. 2008. Final Report Phase 1 – CIALCA: January 2006–December 2008. Progress Report 5. Consortium for Improving Agriculture Based Livelihoods in Central Africa. 94 pp. (Available from http://www.cialca.org/files/files/CIALCA-I_final_technical_report.pdf on 10.02.2014)
- Danso WO, Green KR, Adjei-Nsiah S, [Afreh Nuamah](#) K. 1999 Financial appraisal of plantain sucker production in Ghana. *Musafrica* 13:4–7.
- Eden-Green S. 2008. C3P Evaluation Report final. 11 July 2008. 17pp.
- Eden-Green SJ. 2004 How can the advance of banana Xanthomonas wilt be halted? *InfoMusa* 13:38–41.
- Edmeades S, Smale M, Kikulwe EM, Nkuba JN, Byabachwezi MSR. 2007. Characteristics of banana-growing HH and banana cultivars in Uganda and Tanzania. In: Smale M, Tushmereirwe WK, eds., *An Economic Assessment of Banana Genetic Improvement and Innovation in the Lake Victoria Region of Uganda and Tanzania*. Washington, DC: IFPRI, p. 49–76.
- Jacobsen K. 2013. Review of seed systems for bananas and plantains (*Musa* spp.). Working paper for the Seed Systems Working Group of Roots, Tubers and Bananas. 56pp.
- Jagwe J, Ouma E, van Asten P, Abele S. 2008. Banana Marketing in Rwanda, Burundi and South Kivu. CIALCA Project Survey Report.
- Karamura D. 2011. Report on economic significance of banana varieties other than Cavendish in Uganda. Part 1 of 3 in: Case study: Economic significance of banana varieties other than Cavendish in Uganda. Paper prepared by Bioversity International, CIRAD, and IITA for the Committee on Commodity problems, Intergovernmental group on bananas and tropical fruits, Fifth session, held in Yaoundé, Cameroon, 3–5 May 2011. 38 pp.
- Karamura D, Mgenzi B, Karamura E, Sharrock S. 2004. Exploiting indigenous knowledge for the management and maintenance of *Musa* biodiversity on farm. *African Crop Science Journal* 12(1):67–74.
- Karamura E. 2008. Strengthening the capacity of regional NARS to sustainably manage outbreaks of banana Xanthomonas wilt. Final Technical Report: Xanthomonas wilt of bananas in East and Central Africa. Bujumbura, Burundi.
- Karamura E, Johnson V. 2010. Strengthening the capacity of the National Agricultural Research Systems (NARS) to sustainably manage the outbreak of banana Xanthomonas wilt in East and Central Africa. In: *Scientific and Technical Information and Rural Development*. IAALD XIIIth World Congress, Montpellier, 26–29 April 2010. 7 pp.
- Karamura E, Osiru M, Blomme G, Lusty C, Picq C, eds. 2006. Developing a regional strategy to address the outbreak of banana Xanthomonas wilt in East and Central Africa. *Proceedings of the Banana Xanthomonas Wilt Regional Preparedness and Strategy Development Workshop held in Kampala, Uganda, 14–18 February 2005*. Montpellier: INIBAP, 94 pp.
- Kikulwe EM, Mowakunda K, Byabachwezi MSR, Nkuba JM, Namaganda J, Talengera D, Katungi E, Tushemereirwe W. 2007. Development and dissemination of improved banana cultivars and management practices in Uganda and Tanzania. In Smale M, Tushemereirwe W, eds. *An economic*

- assessment of banana genetic improvement and innovation in the Lake Victoria Region of Uganda and Tanzania. Washington, DC: IFPRI Research Report. p. 37–48. (Available from <http://www.ifpri.org/sites/default/files/publications/rr155.pdf>)
- Mobambo P, Staver C, Hauser S, Dheda B, Vangu G. 2010. An innovation capacity analysis to identify strategies for improving plantain and banana (*Musa spp.*) productivity and value addition in the Democratic Republic of Congo. *Acta Horticulturae (ISHS)* 879:821–828.
- Njukwe E, Tenkouano A, Amah D, Sadik K, Muchunguzi P, Nyine M, Dubois T. 2007. Training Manual: Macropropagation of Banana and Plantain. Ibadan: IITA. 23 pp.
- Nsabimana A, Gaidashova SV, Nantale G, Karamura D, Van Staden J. 2008. Banana cultivar distribution in Rwanda. *African Crop Science Journal* 16(1):1–8.
- Ocimati W, Ssekiwoko F, Karamura E, Tinzaara W, Eden-Green S, Blomme G. 2013. Systemicity of *Xanthomonas campestris* pv. *musacearum* and time to disease expression after inflorescence infection in East African highland and Pisang Awak bananas in Uganda. *Plant Pathology* 62(4):777–785.
- Ouma E, van Asten P, Umuhoza N, Zagabe R, Muhiwa K. 2011. Banana seed systems in Central Africa: Constraints and cost-benefit assessments. Survey report on banana macropropagation and conventional banana sucker trade in Rwanda, Burundi and Eastern DRC. CIALCA, 34 pp.
- Qaim M. 1999. Assessing the impact of banana biotechnology in Kenya. ISAAA Briefs No. 10. ISAAA: Ithaca, NY. 48 pp.
- Rao EJ, Qaim M. 2011. Supermarkets, farm household income, and poverty: Insights from Kenya. *World Development* 39:784–796.
- Sivirihauma C, Ocimati W, Vutseme L, Blomme G. forthcoming. Getting a grip on *Xanthomonas* wilt of banana: Symptomless suckers from heavily diseased fields can be used to establish new and productive plantations. *Plant Pathology*.
- Staver C, Lescot T. 2013. Propagating quality planting material to improve plant health and crop performance: Key practices for dessert banana, plantain and cooking banana – An illustrated guide. Montpellier, France: Bioversity International. 56 pp.
- Swennen R, Ortiz R. 1997. Morphology and growth of plantain and banana. IITA Research Guide N° 66. Ibadan: IITA.
- Tinzaara W, Gold CS, Tushmereirwe W, Bandyopadhyay W, Eden-Green S. 2006. The possible roles of insects in the transmission of banana *Xanthomonas* wilt. In: Saddler G, Elphinstone J, Smith J, eds. Presented at the 4th International Bacterial Wilt Symposium held at the Central Science Laboratory, York, UK, 17–20 July 2006.
- Verwimp P. 2002. Agricultural Policy, Crop Failure and the “Ruriganiza” Famine (1989) in Southern Rwanda: A Prelude to Genocide? Discussion Paper Series (DPS) 02.07, Development Economics, Center for Economic Studies, Leuven. 60 pp.

Vigheri N, Lubanga L. 2006. Banana Xanthomonas wilt in DR Congo. In: Karamura E, Osiru M, Blomme G, Lusty C, Picq C, eds. Developing a Regional Strategy to Address the Outbreak of Banana Xanthomonas Wilt in East and Central Africa. Montpellier, France: INIBAP. p. 17–18.

CHAPTER 14

Responding to Two Cassava Disease Pandemics in East and Central Africa

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Abstract

The GLCI was a 4.5-year cassava project operating across six countries and with more than 50 implementing partners. The project brought together national and international research, government, and NGOs in a single network tasked with producing and delivering disease-tolerant cassava planting material to more than 1.1 million farm families in East and Central Africa. When the project started, the main disease constraint was CMD and, secondarily, CBSD. During the course of the project, CBSD, which had been endemic to coastal East Africa since the 1930s, became endemic in Kenya, Uganda, and Lake Zone Tanzania. At the beginning of the project, there were excellent CMD-resistant cassava varieties which were the basis for decentralized multiplication and distribution of planting material. However, nearly all local varieties and CMD-resistant varieties have proven to be highly susceptible to CBSD.

Rationale

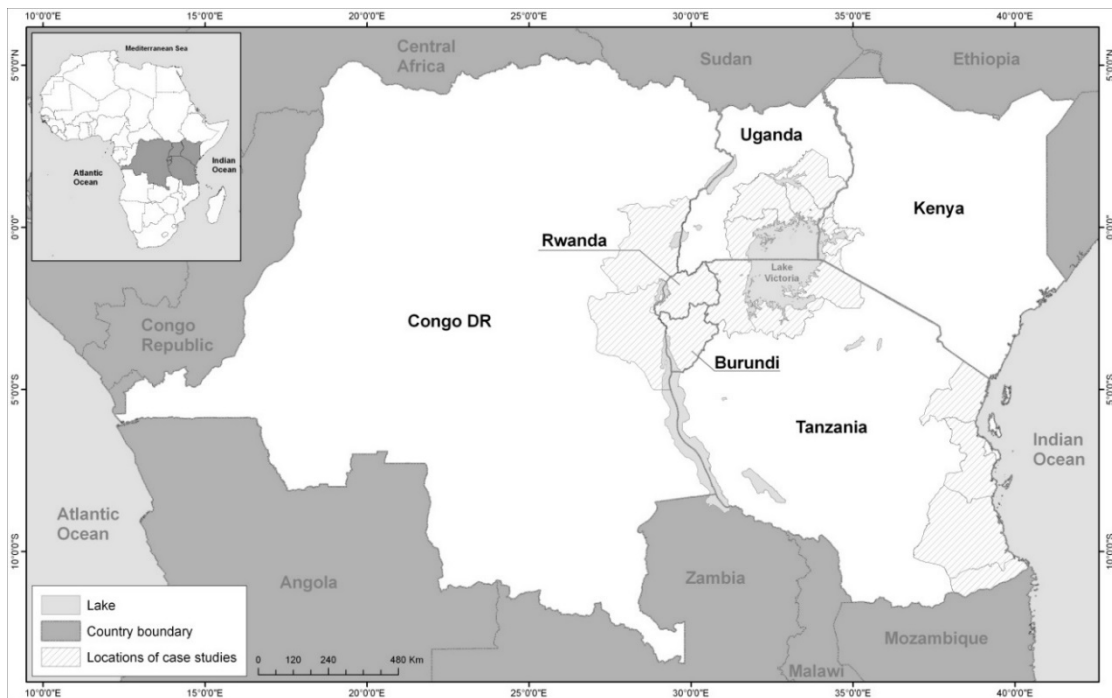
To respond to the dual disease pandemics of CMD and CBSD in East and Central Africa, and to protect and promote food security and incomes of targeted populations.

1. The intervention

The GLCI was a 4.5-year project running from late 2007 through mid-2012. It aimed to strengthen the capacity of more than 50 partners to prepare for and respond to CMD and the then-emerging CBSD that threatened food security and incomes of cassava-dependent farm families in six Great Lake countries: Burundi, DR Congo, Kenya, Rwanda, Tanzania, and Uganda. The program vision was that by 2012, more than 50% of farm families (1.15 million) in targeted priority areas would access planting material of farmer-selected, improved varieties, resulting in a recovery in cassava production to at least pre-epidemic levels and in increased food security.

The initiative was led by CRS, an international NGO, and with technical backstopping from IITA and the UK's Food and Environmental Research Agency. Key partners at national levels included the cassava agricultural research programs as well as plant protection and seed inspectorate agencies under the MoA in each of the target countries. Seed production and disease awareness activities were scaled

through working with more than 2,000 FGs that were organized and managed by three dozen CBOs across the six GLCI countries. During the course of the project, GLCI partners collectively learned and shared experiences on cassava seed systems. Several innovative approaches were used to achieve scale in the GLCI seed system: decentralized production and dissemination; the development and application of quality standards for seed producers; promoting coordination and traceability in the seed system; and the use of disease surveillance, field sampling, and testing to manage the threat of CBSD.



Cassava planting material under GLCI was euphemistically called “self-propagating medicine” because, at the start of GLCI, most of the cassava varieties produced and disseminated were resistant to CMD, the primary cassava seed system constraint. To maximize the dissemination and use of the disease-resistant planting materials, GLCI pursued a highly decentralized production and dissemination approach. Average seed production sites were less than 1 ha, with thousands of production sites across the intervention area.

Dissemination of planting material was done at the seed production site using vouchers. Voucher recipients were identified by local authorities and CBOs, and seed producers maintained records of voucher recipients. The recommended average amount of planting material per beneficiary was 20–25 full stems (i.e., 100–125 cuttings of 4–6 nodes) per farmer receiving planting material. This approach was referred to as “small is beautiful,” and enabled a single cassava seed field to serve more than 500 farmers. And although decentralization increased the demonstration effect (i.e., farmers more readily sought, accessed, and adopted improved, disease-tolerant varieties when they witnessed the varieties’ performance), the approach also required more resources to provide technical support and quality assurance of seed multiplication fields.

Framework: Cassava in Burundi, DR Congo, Kenya, Rwanda, Tanzania, and Uganda

Stakeholder	Availability/ supply	Accessibility			Quality, variety (incl. biodiversity)	Health, genetic purity, physiological age, & physical quality
		Delivery channel features	Affordability / profitability issues	Info to create awareness & demand		
Polymakers	With the suspension of open quarantine due to CBSD, seed was produced within each country	Virtually no official movement of material between countries	Disease-resistant planting material was highly sought after in disease endemic zones	Improved understanding of disease (CMD and CBSD) informed the development of a pest risk analysis guideline	Few countries had an explicit national seed policy for cassava that was put into practice before GLCI	Planting material loss in transit from source site to field of use was a common problem not addressed by policy
National research	Varieties resistant to CMD-Ugandan variant (CMD-UG) were not uniformly available across the different GLCI countries	Very low level of traceability in cassava seed systems	Economics of cassava production for early generation seed was not well understood	In each country a few CMD-UG resistant varieties were widely promoted	Disease-resistant varieties and germplasm sharing between countries was limited	Limited capacity to provide technical backstopping & support to cassava seed producers
International research	Nearly all CMD-UG-resistant varieties that were promoted originated from IITA Ibadan	International germplasm movement in GLCI was very limited	Virtually no effort to put a monetary price on planting material in GLCI	Knowledge of CBSD transmission & performance of CMD-UG-tolerant varieties to CBSD was not known	Performance of germplasm across countries was closely monitored & reported throughout course of GLCI	
Farmer organizations	More than 2,000 FGs became seed producers	High level of decentralization	GLCI did not promote the sale of material although seed producers sold up to 50% of production	Farmers knew about and demanded disease-tolerant planting material	Adaption & deployment at scale of QDS (quality management protocol)	Physiological status of planting material was excellent as distances were short
NGOs	Managed source sites (feeding FG sites) with the support of national research	Varieties alone were not an effective response in CBSD endemic zones		Posters, pamphlets, & radio jingles messages were verified by research	NGOs with national research technical support were the backbone for extension efforts	Issues with physiological status/ stem quality due to long distances & time gap between harvest & planting
Farmers	Massive demand for planting material in disease endemic areas	More than 1 million farmers directly accessed new cassava varieties through GLCI-supported seed fields	Purchase of cassava planting material was widespread, & increased as result of the diseases	Pamphlets, posters, and radio jingles were widely used to communicate to farmers	Farmer knowledge & practice of cassava seed quality improved as result of GLCI	The challenge of plant health quality created a receptive environment for QDS and the use of seed standards

Theory of change

Improved disease monitoring and forecasting, combined with improved farmer-acceptable varieties and a mechanism to deliver these on a massive scale, would lead to increased production and improved HH security. This would require a thorough understanding of the epidemiology of cassava diseases and their diagnosis, the identification of disease-resistant varieties, the development of appropriate seed production systems, and access to markets to create a demand-driven system. Developing these strategies was contingent on strengthening coordination and integration of many players, from farmers and CBOs, to national bodies and regional organizations. The scaling approach of GLCI was based on the effectiveness of promoting oversight and accountability within a decentralized seed production model based on thousands of FGs and fields with relatively small plots (under 2 ha).

2. General context

2.1 TYPE OF FARMING SYSTEMS

Across Africa, cassava is valued for its broad ecological adaptation, low labor requirements, ease of cultivation, and high yields. It is widely cultivated because it can be successfully grown in poor soils and with marginal rainfall. The crop has the significant advantage of a flexible harvest date, so the roots can be unearthed when people need them. Although known for its low market value, fast spoilage after harvest, high bulk, and water content, cassava remains a reliable staple crop for 200 million Africans and is Africa's second most important food crop after maize (Nweke et al. 2002).

Owing to its suitability in low-input farming systems, cassava production has tripled in SSA over the past four decades. Major producing countries are Nigeria, DR Congo, Ghana, Tanzania, and Uganda. Women are responsible for much of this production and for almost all of the processing and marketing. More than 90% of the production is for people to eat (Hillocks 2001).

Recent increases in the area planted have been a response to erratic and declining rainfall and as cassava has replaced cereals on exhausted soils. Africa is currently the world's largest cassava producer, with an estimated production of 110 million metric tons of fresh roots. Virtually the entire crop is produced by smallholder farmers on 12 million ha (FAOSTAT 2005).

2.2 MARKET IMPORTANCE OF CASSAVA FOR FARMERS

As Table 14.1 shows, cassava is a crucial food security crop in the region. While much of the harvest is processed and consumed locally, cassava is increasingly being processed and sold to feed urban populations.

Table 14.1. Regional cassava production and consumption

Country	Area planted (ha)	Production (MT)	Per capita production (kg/yr)	Daily intake (g/capita)	% calorie intake from cassava
Burundi	82,000	710,000	134	228	29
DR Congo	1,845,510	14,974,470	435	750	73
Rwanda	116,000	781,640	113	245	32
Tanzania	660,000	7,000,000	273	378	22
Kenya	N/A	630,000	18.2	N/A	N/A
Uganda	405,000	5,031,000	300	309	28

Source: FAOSTAT, June 2007.

2.3. GENERAL CASSAVA SEED SYSTEM CHARACTERISTICS IN THE REGION

East and Central Africa saw an infusion of CMD-tolerant varieties from IITA/Nigeria from the mid-1990s, and this formed the bulk of germplasm in the GLCI countries. Outside of Tanzania and Kenya, there have been limited investments by national research programs to conduct cassava breeding before the arrival of the CMD-Ugandan variant (CMD-UG) pandemic, which struck the region in the early 2000s. CMD-UG-resistant germplasm was promoted in the region through a partnership between IITA and NARS partners. The main source for germplasm for this region has been the IITA collections at Serere and Namulonge in Uganda. Promising cassava materials moved through open quarantine arrangements to neighboring countries, and the most disease-resistant and farmer-preferred varieties were identified. There is widespread recognition for the need to continue breeding for resistance to pests and diseases while improving on the taste and the nutritional value of cassava.

However, production methods are generally suboptimal in much of Africa, particularly in the more subsistence-oriented parts of Eastern Africa. Here, cassava is produced with traditional varieties and poor quality planting material, but also with suboptimal planting densities and inadequate weed, pest, and disease management. Virtually no mineral fertilizer is used on cassava, and soil nutrients are seldom replenished. The resulting yields of 5–9 t/ha compare unfavorably with levels of 25–35 t/ha obtained in low-input, on-station trials in East Africa. Higher yields result from the use of resistant varieties, clean planting material, and improved agronomic practices, demonstrating the scope for productivity enhancement through improved technology (Fermont 2009).

2.4 TRENDS, DEVELOPMENTS, ONGOING CHANGE OF CONTEXT

CMD was the major cassava seed system constraint at the start of GLCI; CBSD was an emerging seed system constraint. Before 2004, CBSD had never been recorded at high incidence above 1,000 masl. CBSD was primarily known as a disease of the lowland cassava-growing areas of East Africa, including the shores of Lake Malawi. However, from late 2004 onwards, CBSD was identified in parts of Southern and Central Uganda. Preliminary survey work confirmed the identity of that virus as the ipomovirus, cassava brown streak virus (Alicai et al. 2007).

CBSD was widely identified in Kenya, Uganda, and in Lake Zone Tanzania from 2006. It is a devastating disease that causes loss of root production and quality. The disease can render susceptible varieties unusable if cassava roots are left in the ground for more than 9 months. Like CMD, CBSD is a viral disease, and is spread both by planting infected cuttings and by a whitefly vector, *Bemisia tabaci*. CBSD incidence was highest and severity greatest among the CMD-resistant varieties that were promoted for the management of the CMD pandemic. CBSD symptoms were seen in diverse local varieties, although symptoms were less severe. The spread of the viruses causing CBSD and CMD correlated with the great abundance of the white fly in the Lake Zone Region (Figure 14.1). Unlike the mosaic symptoms of CMD, the foliar symptoms of CBSD are less conspicuous, and farmers are often unaware of the problem until the roots are harvested and the corky, yellow-brown necrotic rot becomes evident (Legg and Ntawarahungu 2007).



Symptoms of the potentially devastating CBSD.
Photo by Carl Walsh

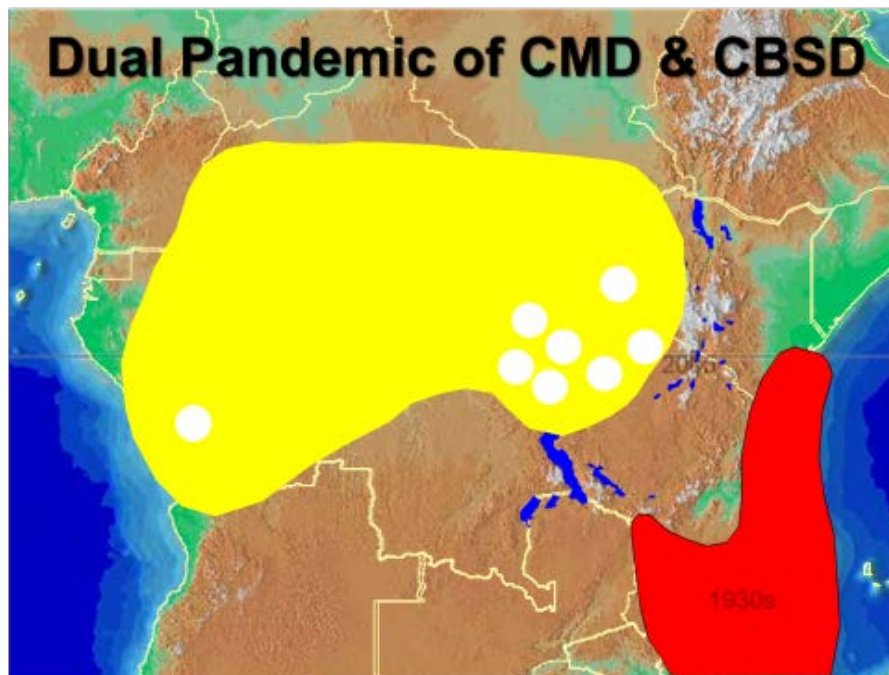


Figure 14.1. Spread of CMD and CBSD over time. (Legend: yellow represents CMD, red is CBSD, and white dots indicate CBSD reports since 2004.) Source: James Legg, IITA.

CBSD has been endemic to coastal East Africa (Tanzania, Kenya, and Mozambique) since the 1930s. But there had not been reports of CBSD symptoms in medium to high altitudes of Central Uganda, western Kenya, or the Lake Victoria zone of northwestern Tanzania. In the GLCI project area, most local cassava varieties and CMD-resistant varieties have proven to be highly susceptible to CBSD.

During the course of GLCI, CBSD diagnostics and disease epidemiology became much better understood. Discovery of a complete cassava genetic code in 2007 led to rapid improvement in molecular diagnostic methods. In 2010, a second species of cassava brown streak viruses, Uganda cassava brown streak virus (UCBS-V), was formally recognized. Both CBSD species cause the same symptoms. In 2010, IITA published a non-peer reviewed case study on field epidemiology of CBSD in the Lake Zone, Tanzania, which highlighted the low efficiency of white fly transmission in CBSV compared with CMD. The study suggested that field isolation was an effective management strategy in endemic CBSD zones (Legg et al. 2010).

3. Seed users

3.1 SEED ACQUISITION AND ACCESSIBILITY OF SEED

3.1.1 *Before the intervention*

Cassava multiplication and dissemination of CMD-tolerant germplasm, originating from IITA in Ibadan, Nigeria, was common in East and Central Africa by the end of the 1990s. Interventions with varieties tended to offer a high impact and good return on donor investment. The aim was to increase the availability and farmer access to improved cassava mosaic-resistant varieties that were developed through the IITA West Africa breeding program. During this period, planting material moved from one country to another under an open quarantine policy. This greatly facilitated access to starter material for seed multiplication.

Cassava multiplication and dissemination activities tend to be centralized and to use large multiplication blocks. Planting material was harvested and transported long distances across and sometimes between countries. This demanded significant resources for transportation as cassava planting material is bulky. The modus operandi from previous and ongoing cassava stem multiplication and dissemination efforts in GLCI countries was more centralization, larger fields, a greater focus on primary and secondary sites, large quantities of planting material received by individual farmers and out-growers, and little systematic effort to disseminate material in small quantities to farmers. A common critique of these multiplication and dissemination activities was the large budget allocated to transport and high losses because planting material dried out in transit (Bonnard 2004).

From 2006 to 2008, IITA and CRS jointly implemented an emergency response seed system program that addressed both CMD and BXW. The use of on-farm vouchers to disseminate cassava stems was successfully piloted in western Kenya (Walsh et al. 2006) and subsequently replicated throughout the six countries of C3P (see Chapter 12). The C3P project area included the same six countries of GLCI and many of the same local NGOs (Table 14.2).

Table 14.2. Improved cassava varieties promoted in Great Lakes Region as of September 2007

Burundi	DR Congo	Kenya	Rwanda	Tanzania	Uganda
Varieties propagated at start of GLCI					
MM96/0287	MM96/0287 (Liyayi)	SS4 (Nase 4)		MH96/3075B (Belinde)	MH97/2961
MM96/7204	MM96/1666 (Sukisa)	TMS 30572 (Nase 3)		MM96/4619 (Meremeta)	I92/0067
	MM96/3920 (Sawasawa)			MM96/4684 (Mkombozi)	
	MM96/7752 (Mayombe)			MM96/5725 (Nyakafuru)	
	Butamu			MM96/8233 (Rangi Mbili)	
	Disanka			MM96/8450 (Kibaya)	
	M'vuazi			I92/0067 (suma)	
	Nsasi				
Varieties withdrawn from GLCI multiplication due to CBSD					
MM96/0735			I92/0057	TMS 4(2)1425	
MM96/5280			95NA/00063	TME 14	
MM96/7688				MH95/0414	
Abbey lfe					

Source: NARS staff from all six GLCI countries, Sept. 2007 GLCI planning meeting in Dar es Salaam.

3.1.2 What changed as a result of the intervention

When GLCI closed at the end of May 2012, it had reached 1.19 million direct beneficiaries with planting material, exceeding the project target by 200,000 HH (Table 14.3).

Table 14.3. GLCI end-of-project direct beneficiaries served with clean seeds by 31 January 2012

Country	No. of fields disseminated to	Beneficiaries served outside multiplication groups	Beneficiaries served within multiplication groups	Total beneficiaries served
Burundi	349	118,440	13,500	131,940
DR Congo	1,747	705,075	59,237	764,312
Kenya	238	63,904	8,981	72,885
Rwanda	530	109,934	11,378	121,312
Tanzania	384	44,104	8,595	52,699
Uganda	92*	39,701	7,381	47,082
Summary	3,340	1,081,158	109,072	1,190,230

GLCI established, over the life of the project, more than 4,000 tertiary sites for producing cassava planting material, on an average of 0.31 ha per site (Table 14.4).

Table 14.4. GLCI seed multiplication sites, evidence of decentralization

Country	Secondary sites		Tertiary sites	
	Total # sites	Avg. size (ha)	Total # sites	Avg. size (ha)
Burundi	107	0.50	739	0.35
DR Congo	124	1.02	2,161	0.21
Kenya	81	0.73	611	0.33
Rwanda	82	1.10	927	0.43
Tanzania	105	0.63	725	0.30
Uganda	78	0.88	375	0.47
Summary	577	0.80	5,538	0.31

3.2 AFFORDABILITY OF PLANTING MATERIAL

Although decentralization increased costs of monitoring production sites, GLCI achieved real and significant benefits from its “small is beautiful” approach. GLCI was able to support a robust field management structure of 55 partner supervisors, 210 paid field agents, more than 750 voluntary field agents, and about 3,000 FGs, which were the dominant cassava multipliers under GLCI. Considering all the costs of GLCI and dividing by the number of direct recipient farmers (not including the two to three farmers that direct recipients reported sharing planting material with), the cost per direct stem recipient was \$16.80, and the cost per production site was \$3,448 (Table 14.5).



Small is beautiful: community-level cassava sites for multiplying planting material.
Photo by Carl Walsh

Table 14.5. Decentralization—cost per production site and recipient farmer in GLCI

Country	Total budget (US\$)	Total # of sites	Unit cost (\$) per site	Total # of farmers	Cost (\$) per farmer
Burundi	1,448,070	875	1,655	138,891	10.4
DR Congo	4,400,111	2,333	1,886	837,125	5.3
Kenya	952,551	715	1,332	83,992	11.3
Rwanda	1,563,021	1,082	1,445	160,035	9.8
Tanzania	2,334,185	1,016	2,297	72,556	32.2
Uganda	1,470,001	492	2,988	50,831	28.9
Region	10,353,665	n/a	n/a	n/a	n/a
Summary	22,521,604	6,513	3,458	1,343,430	16.8

Source: GLCI Phase One Financial Report and GLCI Database/Project Reports/Dissemination.

The unit cost per site is an estimate based on taking the total budget per country and dividing it by the total number of production sites. In practice, only seed producers in DR Congo and Rwanda received an input subsidy, which was used to offset the cost of land. Seed producers were compensated by being allowed to keep or sell at their discretion a percentage of the stems they produced.

Over 1.3 million farmers accessed GLCI planting material free of charge. Each of these recipient farmers received a small amount of planting material from a GLCI seed production site. Nearly all of the stems were distributed using a voucher-based system to promote accountability. However, at least one-third of the stems at each GLCI production site were kept by the producer organization for its own use or for sales (Table 14.6). GLCI did not trace the planting material which was sold.

Table 14.6. Partners' practices of payment and stem allocations of tertiary sites

Country	Payment	Stem allocations
Burundi	0	Variable, up to 40% for dissemination
DR Congo	\$200/ha	Variable, up to 70% for dissemination
Kenya	\$1 for 35 stems	Variable, multipliers were encouraged to sell stems
Rwanda	\$300/ha	2/3 (dissemination), 1/3 (multiplier)
TZ coast	0	50% (dissemination), 50% (multiplier)
Uganda	0	50% (dissemination), 40% (multiplier)

3.3 SEED QUALITY

3.3.1 Before the intervention

The quality management protocol (QMP) used under GLCI was first piloted under C3P (see Chapter 12), in the same countries and with largely the same partners. The QMP established stem production standards for cassava stem multipliers. The QMP included guidelines for field isolation distance, and identified and described the specific pests and disease that were included in the QMP.

3.3.2 What changed as a result of the intervention

In the context of two diseases, seed quality was of the greatest concern. GLCI exercised extreme caution to make sure that no infected material was multiplied or disseminated. Lab testing by real-time polymerase chain reaction (PCR), a common approach used in the agriculture industry whereby small amounts of DNA are extracted from leaf samples and amplified before testing for specific pathogens, was used to ensure that a subset of GLCI source sites were free of CBSV. The lab testing of a subset of source sites complemented the use of QMP, which was based strictly on the visual identification of symptoms and was carried out on all stem production sites.

At the start of GLCI, the QMP drafted and piloted during C3P was discussed at a two-day meeting with partners, NARS, country National Plant Protection Organization officials, and IITA in order to produce a new draft to include CBSD by 30 June 2008. NARS, partners, and plant health inspectors then reviewed and tested the QMP at the Learning Alliance meeting, a GLCI project event in January 2009, and used QMP for the March 2009 plantings. The QMP was revised further after the March plantings

when appropriate diagnostics for CBSV became available. The revised QMP was being applied in all countries by 2010.

Rigorous control using QMP in CBSV-endemic regions resulted in a marked improvement in quality and reduced waste as evidenced by the source site testing. Uganda took the application of QMP seriously and applied it to all primary and secondary multiplication sites to discard obviously infected fields. This practice saved much time and expense in conducting unnecessary lab testing for a great number of fields.

Such decentralized quality control and plant health processes were slowly being appreciated, instituted, and documented across GLCI partners, sites, and countries. A QMP French training manual was developed in 2010, and used as part of a training in Rwanda facilitated by GLCI-Rwanda partners, with Rwandan MoA and plant health support. GLCI staff from Burundi, DR Congo, and Rwanda traveled to Musoma, Tanzania, in June 2010, to see CBSV in the field; talk to Tanzanian plant health staff, government officials, and CRS partners; and to participate in field and focus group meetings with affected farmers. All participants noted a renewed understanding of the importance of QMP after having participated in this GLCI-sponsored event. By 2011, the dissemination activities indicated that partners had fully instituted and implemented the approach. This showed that QMP was a practical, low-cost, and decentralized quality control process, though there was difficulty drawing analytical insights from QMP data that were not always accurately entered.

All of the multiplication sites—primary, secondary, and tertiary—were coded to reflect the country, partner, district, planting season, and the source site from which the seed came and the destination (where the planting material went). These data were recorded in the onward multiplication forms, and this form was submitted for all primary and secondary sites at the time of harvest and seed distribution (Figure 14.1). Cassava stems from the tertiary sites was disseminated, rather than multiplied further, and the forms showed from which primary or secondary sites the seeds were received.

Tracing the source and destination of the seed was essential in order to manage both viral diseases and for disease surveillance and seed quality. When infection was detected, this information allowed the project to trace back the source material and to make decisions on further distribution of the material.

4. Seed producers and seed availability

4.1 THE MODEL

GLCI set up the following protocol with FGs for tertiary multiplication to ensure uniformity and quality of practices in multiplication and dissemination:

- Select FGs.
- Make a contract in which the payment for the stems will be given when the dissemination record has been turned over.

- Provide planting material and technical backstopping on planting, agronomy, and disease management.
- Partners monitor the field four times a season, of which two are QMP at months 5 and 11.
- Dissemination plan prepared by the partner and approved by the local authorities, and beneficiaries chosen by a selection committee consisting of local authorities, FG representatives, paid field agent, and civil society.
- Each beneficiary receives a voucher; in nearly all cases these were provided for free.
- If the site fails QMP, GLCI does not buy the material.
- If the site passes, partner and local authorities identify beneficiaries who are informed where they can go and get clean material.
- Field dissemination date is announced to beneficiaries.
- Beneficiaries walk to the harvested field and exchange the voucher for planting material.
- Dissemination monitored and facilitated by the partner; voluntary field agent completes dissemination record, based on the vouchers received.
- Dissemination record validated by the selection committee and submitted to the partner or CRS country program manager, along with the vouchers as proofs of dissemination.

4.2 BENEFITS FOR THE FARMERS

Advantages

- Beneficiaries had a short distance to walk to and from the dissemination sites.
- Seed did not travel far, which meant less chance of the planting material drying and dying.
- Less risk in case of disease, as only small plots of multiplication sites would be lost.
- Each beneficiary received 100–125 cuttings. Assuming a multiplication rate of 10 was enough to plant 1,000 m² of cassava the following year. This enabled more farmers to benefit.

Easier access to smaller plots of land and lower labor and management challenges with smaller multiplication plots encouraged GLCI to recommend multiplication sites be a maximum of 1 ha and a minimum of 0.25 ha for tertiary sites. This necessitated greater decentralization to increase the demonstration effect (i.e., farmers would more readily seek and adopt improved disease-tolerant varieties when farmers witness the material's performance), but smaller plots also resulted in GLCI making concerted efforts to site fields 10 km apart. Smaller, more decentralized fields promote the transport of planting material in full stems on farmers' heads in a single bundle as opposed to cuttings or mini-stems in bags loaded on vehicles. Full stems have a shelf life of several weeks versus several days for the mini-stems.

Disadvantages

The entire system was predicated on external subsidies. In the course of GLCI, it was unclear what aspects of the program might continue without project support. This of course leads to a critique of the

extent of sustainability of such heavily subsidized seed programs. An economic argument can be made that the program investment of \$16.8 per farmer was much smaller than the likely returns. However, the program established extension, testing, and inspection services which could not be paid for by the seed producers or by the host governments. The program put little effort into assessing different cost recovery models which might offset or pay for these services. From the standpoint of promoting the emergence of a commercial cassava seed system, GLCI was a resounding failure. But from the perspective of mitigating the effects of two cassava diseases and earning the donor a significant return on investment, GLCI was a resounding success.

4.3 QUALITY ASSURANCE AND REGULATION

As described elsewhere in this chapter, GLCI implemented a decentralized quality control approach for its multiplication sites (referred to as QMP). This decentralized quality assurance process was carried out with extension staff employed by GLCI and with the participation of the seed producer. The QMP involved inspecting 100 plants per seed production field, visually assessing plants for disease symptoms, and confirming that the variety under multiplication was true to type (see also Section 5.2 below).

5. Regulation and policy affecting farmers' use of quality seed

5.1 GENERAL POLICIES AND SEED REGULATION

During the course of GLCI, there were no changes to cassava seed policy in any of the six GLCI countries, but there was more emphasis on coordination and consideration of cassava seed policy. This was promoted by GLCI through several meetings and a workshop to start the development of a cassava pest risk analysis on cassava disease in the Great Lakes Region, which was a key policy output of the GLCI project. Issues like the need to reconsider an open quarantine process (i.e., allowing under certain circumstances for the movement of cassava planting material between neighboring countries in the Great Lakes Region) were raised at platform meeting in the course of GLCI.

6. Seed health and quality

Before the GLCI intervention, a QMP for cassava was developed and employed by C3P. Under that project, QMP was done on a very limited scale and provided the basis for scaling QMP under GLCI. The GLCI multiplication and dissemination system was organized in a hierarchical manner: a few primary sites feeding many district-level secondary sites that provided planting material for thousands of community-level multiplication sites, called tertiary sites. The main threat for the GLCI multiplication system was the spread of viruses that cause CBSD. Two species of CBSVs are now recognized: CBSV and CBSUV.



A farmer digs up a cassava root to show that it is disease free.
Photo by Carl Walsh.

CBSD risk assessment mitigation in GLCI involved surveillance and testing, which was donor mandated and not based on farmer cost-benefit analysis. Neither the epidemiology of CBSD nor its economic impact on farmers was well enough understood during GLCI for this cost-benefit analysis to be credible. From the standpoint of the donor, GLCI could do more harm than good if the project spread CBSD; this was the justification for an investment into CBSD mitigation. To minimize the risk of spreading CBSVs through the GLCI multiplication scheme, primary sites and most secondary sites in CBSD-threatened areas were tested using virus laboratory diagnostic methods (real-time PCR) for the presence of CBSVs. CBSD-threatened areas were determined by surveillance activities undertaken by IITA, notably annual disease surveys. These were appropriate activities; the disease surveys identified where CBSD disease was present and thus was critical to identifying where multiplication source sites, or primary sites, would need lab testing.

Only GLCI source sites having no positive virus test results were used as source sites or primary sites for secondary or tertiary sites—the zero tolerance approach. The sampling frame of 300 plant leaves per field (tested in 10 batches of 30 plants) was determined in order to detect, with 95% confidence, a 1% incidence of CBSD. The GLCI approach to CBSD in terms of sampling frames for testing and diagnostics emphasized source fields and high CBSD areas while focusing significantly less on tertiary sites and CBSD-disease free zones.

7. Lessons

Decentralized production and dissemination

Decentralization through thousands of multiplication sites averaging under 1/3 ha and with recipient farmers accessing only 100 cuttings was very effective in achieving scale in GLCI. However, this approach was predicated on CMD-resistant materials that were prevalent in GLCI countries at the start of the project. This approach is not appropriate in CBSD-endemic zones because there are currently no CBSD-resistant varieties.

Varietal dispersion data from GLCI dissemination sites, combined with post-GLCI varietal adoption studies, could provide important information on how much multiplication and dissemination is needed in a zone before a variety is easily available to all. Given the low multiplication rate of cassava, this would be useful to maximize returns on future public sector cassava seed system investments.

Quality management protocols

GLCI effectively employed visual field inspection protocols, known as QMP, to screen source sites to avert costly laboratory testing and to provide an opportunity to apply cassava health knowledge across thousands of multiplication sites while training hundreds of field staff. To be sustainable, and to function without an external subsidy, certification and quality control must have an economic basis; and the costs to implement them must be lower than the benefits of the improved seed quality. Although QMP was a practical approach to assessing the quality of planting material in seed production fields, and the costs to implement QMP could be easily calculated, the economic benefits of doing QMP, even in CBSD-endemic zones, were not well understood.

Even with a strong economic argument to justify public sector investment in QMP, it remains highly unlikely for QMP to continue in any form in any GLCI country without significant donor funding. This is because national plant protection organizations lack the capacity to promote, coordinate, and backstop the application of minimal plant health standards for cassava stem production fields.

Targeted dissemination and traceability

Transparency in the GLCI seed system—understanding and documenting the origin and destination of all fields—was an important innovation. But it is unclear to what extent other donor- or government-funded cassava seed system projects will employ such tools and, more generally, to what degree accountability and transparency are actually considered valuable for public sector seed investments.

Disease mitigation via surveillance, sampling, and testing

The use of a risk mitigation framework through combining surveillance, visual field inspections, and testing was unique to GLCI. The application of this framework was critical to preventing the dissemination of any diseased planting material; however, the use of the QPM has not been linked to any demonstrable economic benefits. It is hoped that learning from GLCI will facilitate the smarter use of low-cost and accurate diagnostic testing in a systematic framework in which disease surveillance determines the scope of testing and testing regimes and quality control processes are paid for by seed producers and seed consumers.

In the Great Lakes Region of East and Central Africa, cassava and cassava seed systems will continue to attract public sector investment, given the importance of the crop to food security and farm family livelihoods. However, in the absence of effective coordination among donors and a multitude of cassava partners, it is unclear how effective ad hoc, one-off, and unilateral public sector investments can be. The GLCI network of 50 plus partners, comprising civil society organizations, local governments, plant protection organizations, and agricultural research, was an ideal platform for promoting collaboration, learning, mutual accountability, and innovation at scale across six countries.

References cited

- Alicai T, Omongo CA, Maruthi MN, Hillocks RJ, Baguma Y, Kawuki R, Bua A, Otim-Nape GW, Colvin J. 2007. Re-emergence of cassava brown streak disease in Uganda. *Plant Disease* 91:24–29.
- Boni SB, Legg J. 2008. C3P cassava planting material quality management in the multiplication sites. Technical report for Burundi, DR Congo, Kenya, Rwanda, Tanzania, and Uganda. Implemented by IITA, EARRNET, CRS. Final QMP Report.
- Bonnard P. 2004. An Evaluation of USAID/OFDA Efforts against Cassava Mosaic Disease 1997–2004. (Available from http://pdf.usaid.gov/pdf_docs/PDACF021.pdf)
- CRS. 2013. Final Report on the Great Lakes Cassava Initiative 2013. 137 pp. (Available from <http://www.crs.org/sites/default/files/tools-research/final-report-great-lakes-cassava-initiative.pdf>)

- Fermont AM. 2009. Closing the cassava yield gap: An analysis from smallholder farms in East Africa. *Field Crops Research* 112:24–36.
- Hillocks RJ, Raya MD, Mtunda K, Kiozia H. 2001. Effects of cassava brown streak disease on yield and quality of cassava in Tanzania. *Journal of Phytopathology* 149:389–394.
- Legg J, Boni S. 2007. Quality Management Protocol (QMP): A Guide to the Assessment of Seed Quality and Plant Health within Cassava Multiplication Schemes. Ibadan: IITA.
- Legg J, Ntawarahungu P. 2007. New Spread of Cassava Brown Stream Virus Disease and Its Implication for the movement of cassava germplasm in the East and Central Africa Region. IITA and CRS. (Available from http://www.crs.org/research-publications/solr-search?f%5B0%5D=field_program_area%3A592&f%5B1%5D=field_location%3A758)
- Legg J, Obonyo R, Shirima R. 2010. CBSD Infection and QMP Assessment: Tertiary Sites – Lake Zone of Tanzania within the Great Lakes Cassava Initiative. IITA and CRS.
- Nkuba J, Mushongi C, Maranda E. 2007. Cassava on farm voucher (OFV) evaluation report in Kagera Region. Crop Crisis Control Project Quarter Six Report.
- Nweke F, Spencer D, Lynam J. 2002. *The Cassava Transformation: Africa's Best Kept Secret*. East Lansing: Michigan State University Press.
- Smith J, Macarthur R, Weekes R, Tomlinson T, Adams I, Boonham N. 2012. Assessing risk and management options for multiplication and movement of cassava in the face of CBSD: The experience of the Great Lakes Cassava Initiative. Food and Environment Research Agency, Sand Hutton, York, UK.
- Walsh S, Bigirimana S. 2006. Cassava cutting movement from primary to bulking sites: Case study Burundi, remedies to reduce loss. C3P Brief No 4. IITA and CRS. (Available from http://www.crs.org/researchpublications/solrsearch?f%5B0%5D=field_program_area%3A592&f%5B1%5D=field_location%3A758)
- Walsh S, Odero-Onyango B, Obiero H. 2006. Pilot use of on farm vouchers to disseminate cassava planting material in Western Kenya. C3P Brief No. 5. IITA and CRS. (Available from http://www.crs.org/research-publications/solr-search?f%5B0%5D=field_program_area%3A592&f%5B1%5D=field_location%3A758)

CHAPTER 15

Conclusion: Cross-case analysis of RTB seed

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In this chapter we present a cross-case analysis, using an adaptation of the multi-stakeholder framework for intervening in RTB seed systems (Sperling et al. 2013) (see this book's introduction and RTB 2016). We use the case studies presented in this book to identify ideas for successful RTB seed systems, summarized at the end of each section. We start by describing the types of interventions, then analyze them using the three main functions of a seed system (seed availability, seed access, and seed quality), focusing on the seed users. We then take a closer look at seed producers, policies, and multiplication techniques before concluding with recommendations (see Section 3 below). Throughout this chapter we refer to the case studies using the short names mentioned in Table 1 of the introduction.

Type of interventions, justification, and scale

The 13 interventions featured in this book were justified for different reasons: to support seed system development, to mitigate a crop disease emergency, to improve food security and nutrition, to meet the new opportunities of developing markets, and to promote the adoption of new varieties and technologies. For example, the UPoCA and Marando Bora projects were proposed to give farmers greater access to new varieties. Some of the projects promoted a specific propagation technology, such as aeroponics for potato (Cajamarca, 3G, Gender and seed), minisetts for yam (Yam in Nigeria), and TC for banana (TC and Emergency banana cases).

The case studies also vary in scale, from a few dozen farmers (CONPAPA) at some pilot sites to multinational efforts (such as TC and Emergency banana cases, UPoCA, and GLCI). Most of the interventions are short, 24 months or so. A case with a longer timeframe (CLAYUCA) shows that a project that would have been considered a failure in the short run had a lasting impact when seen several years later. On the other hand, the Emergency banana case would have been considered fairly successful right at the end of the project. But with deeper knowledge of the crop-disease dynamics, it is clear that the macropropagation technique itself was less critical than first thought.

1. Seed system framework: availability, access, and quality

1.1 SEED AVAILABILITY

In times of war or disaster, farmers might find themselves with nothing to plant (see Sperling 2008). But under most conditions, seed is available. In all of the cases in this book, seed was available even before the intervention. In Tanzania (Marando Bora), the OFSP was not always available before the intervention, but other varieties were, as independent market traders were selling vines and neighbors were usually willing to share planting material with each other. Likewise, the potato farmers in the 3G case in Kenya had seed before the intervention, but high-quality seed was in extremely short supply. Also, in the case of Yam in Nigeria, seed was available and could be planted as whole tubers before the AYMT intervention that introduced the miniset technique, thereby reducing the seed cost and improved the seed quality.

Except in dire emergencies, seed is usually available but quality may be an issue (e.g., getting enough healthy seed of a desired variety at the right physiological age). Markets, nutritious new varieties, or introduced pests create demands for seed which seed interventions seek to make available. For example, expanding consumer demand for quality potatoes in the Andes (CONPAPA, Cajamarca) and in East Africa (3G, Gender and seed) creates demand for affordable, quality seed. New processing industries spark demand for new cassava varieties in Nicaragua (CLAYUCA), whereas cassava diseases in Africa leave farmers in need of resistant varieties or virus-free planting materials. In most cases, seed was available before the intervention, but farmers needed a different variety or healthier seed or disease-resistant seed. In other words, farmers did not need more seed, they needed better seed.

Section summary. Under nonemergency conditions, seed availability per se is seldom a problem in RTB seed systems; farmers usually manage to produce or obtain seed. Seed availability becomes a problem, in combination with quality (the final columns shown in the framework tables), of not having enough good, healthy seed of desired varieties.

1.2 SEED ACCESS

Good quality seed may be available, but farmers will not have access to it if delivery channels are poor, if the seed is unaffordable, or if farmers are unfamiliar with it.

Delivery channels. Without an intervention, seed is produced on-farm, shared among neighbors, and sold in a local market. Informal systems by definition are not regulated. Sometimes the informal system delivers low-quality (unhealthy) seed, but not always. Some informal channels are fairly efficient, such as specialized seed potato producers in Peru who bring seed from the highlands for farmers on the coast (Bentley et al. 2001), or potato growers in Malawi who sell seed tubers to farmers from Mozambique (see Gender and seed chapter). In East Africa, farmers who have some moist land may grow sweetpotato that can then provide planting material for other farmers at the start of the dry season (Marando Bora). Informal channels are responsible for delivering seed to most farmers; 80–100% of tropical potato farmers use informal seed (Thomas-Sharma et al. 2015).

Some of the interventions in this book sought to organize farmers into new delivery channels (e.g., TC in bananas, CONPAPA in Ecuador, and Gender and seed in Malawi, and both of the sweetpotato

cases— Marando Bora and Superfoods). Some of these interventions were more successful than others. For example, the Ecuador case was successful because distribution was well organized through a farmers' organization that had been well connected to the market. Projects like 3G or CONPAPA (which include an explicit market component) were more successful than Emergency banana, which lacked this component. Organizational problems plagued the Gender and seed case in Malawi. The sweetpotato cases relied on a lot of organization from the project itself, and the TC case in East Africa was a success where the new community multiplication sites were near their supply (TC labs), their customers (farmers), and where farmers had easy access to markets in the cities.

The projects used different strategies to disseminate new varieties; for example, some used vouchers (e.g., Marando Bora on sweetpotato and GLCI on cassava). But the vouchers have a high administrative cost, and sometimes Marando Bora had to resort to giving planting material away at schools. In the banana TC case, the project created community-level farmer nurseries to distribute the new planting material. CONPAPA used a well-structured farmer organization to distribute seed potato to farmers in Ecuador, based on consumer demand for varieties. UPoCA in seven African countries created community nurseries for growing the new cassava varieties and giving stakes to local farmers, among other initiatives.

There were some cases in which the delivery channels were implemented with private companies (e.g., 3G on Kenyan potato, and CLAYUCA on Nicaraguan cassava), although most of the cases involved public organizations, FGs, and NGOs. Deciding whom to work with will depend on local conditions, and gender. It may be more sustainable and efficient to work with private companies, yet they may reject activities that they do not perceive to be profitable (as described in TC banana).

None of the case studies of this book aimed at improving existing delivery channels (e.g., local markets and traders). Even in cases like Peru, where informal channels have been well described (de Haan et al. 2010; Urrea-Hernandez et al. 2015, for example), the projects did not attempt to use existing channels. However, some interventions were based on improving the quality of farmer-saved seed (e.g., Yam in Nigeria and 3G potato seed in Kenya).

Affordability can be achieved in two ways: either by making the seed cheaper, or by improving the profitability of the system (pay farmers more for their ware produce and they will be able to spend more money on seed). Almost all seed projects contain hidden subsidies to make the planting material cheaper (e.g., the farmers do not pay the salaries of the project members of staff who help to make the seed accessible). Some projects also have formal subsidies (e.g., vouchers), as in both of the sweetpotato projects and the GLCI cassava project; or they give seed away for free, as in the UPoCA cassava project. Another strategy is to make quality seed less expensive by allowing it to be inspected for quality but not formally certified, as with CONPAPA in Ecuador and 3G in Kenya.

Several interventions explicitly connected farmers to new, higher-paying markets (Cajamarca in Peru, CONPAPA in Ecuador, CLAYUCA in Nicaragua, Superfood in Rwanda) while other interventions were encouraged by strong market demand for the final produce (e.g., 3G in Kenya, bananas and cassava in Africa). Several studies had a theory of change that supposed that smallholders would specialize in quality planting materials and become entrepreneurial suppliers of such seed.

In this book, the new seed potato supply in Ecuador was based on explicit demands from farmers for good, cheap seed, which emerged from their participatory market chain analysis (CONPAPA). The yam farmers in West Africa were facing a clear need to lower their seed ratio from a staggering 1:4 (AYMT). Some of the plantain growers in Ghana (TARGET) liked the new hybrids so much that farmers wanted to keep the second generation planting material instead of passing it on to others (i.e., the new seed met farmers' demands). The cassava farmers in Nicaragua appreciated the new cassava varieties enough to keep them alive during the project's hiatus (CLAYUCA). And the farmers in seven African countries seemed to appreciate the new, disease-resistant cassava varieties provided by the UPoCA project. The Kenyan farmers demanded so much of the new potato seed provided by the 3G project that they bought the entire supply, even when growers raised the prices.

Most of the interventions were based on some information about farmer demand, but not necessarily with a rigorous understanding of seed system dynamics. For example, in Emergency banana, there was a clear demand for banana planting materials following the outbreak of BXW. The intervention could not meet the demand, yet farmers eventually learned to use symptomless suckers successfully. Researchers only later confirmed that this was a viable (80% success rate) solution in areas where clean seed is not readily available (Sivirihuama et al. 2015).

Farmers are often willing to pay a small premium for better seed (Van Mele et al. 2011). Farmers generally buy RTB seed when they cannot produce or store seed out of season (e.g., 3G in Kenya) or when they need a new variety (e.g., cassava in Nicaragua or in various African countries, hybrid plantains in Ghana). Farmer demand can only sustain a specialized seed enterprise when farmers are unable to store or produce the seed themselves, or if the seed supply is compromised by pests and diseases.

When farmers do buy seed, they often buy small amounts that they can multiply themselves. Poor HH and vulnerable groups (e.g., women) are not always able to buy seed, even when it is cheap (see Gender and seed case). Farmers may frequently give seed away or exchange it in non-cash transactions (see the Superfood and the Gender and seed cases, and Badstue 2006). In Malawi, women buy cheaper seed, even when they know its quality is poor. Quality seed yields more if it is combined with fertilizer, if the HH can buy it (or make organic fertilizer). For bananas, clean seed produced with new technology (see TC and Emergency banana cases) may initially require more labor than farmers have, resulting in lower, not higher, yields.

As the market develops, farmers increase their income and are able to afford quality seed (see CONPAPA in Ecuador and CLAYUCA in Nicaragua); this was also an assumption in African cassava (UPoCA). In East Africa, the farmers who were near the large cities could sell their bananas at a higher price, so they could in turn afford to buy TC seed (TC case).

Sharing information to improve seed access is where seed interventions have a unique advantage. The informal seed system may share information by word of mouth, but the private sector occasionally confuses farmers with disinformation. This was the case when cotton seed companies in India repackaged previously released genetically modified varieties under new names (Stone 2007), or the seed companies in North America in the 1930s that misrepresented the advantages of hybrid maize (Kloppenborg 2005).

In the cases here, it is also possible that the potato project in Malawi oversold the advantages of DSL of seed, for example. But there are other examples where the intervention used an appropriate information campaign for the public good (e.g., the UPoCA project provided some training to farmers in seven African countries on seed management). The AYMT project (Yam in Nigeria) trained farmers in good seed production practices for on-farm management of seed yam quality. And the potato project in Ecuador made a long-term effort to share information between producers and buyers. The best use of information was the Kenyan potato case, where thousands of farmers were systematically trained to use the new seed and keep it healthy.

Information can also backfire if the intervention fails to actually produce the seed, as happened in Malawi. The project convinced farmers of the value of the new potato seed, but could not provide enough of it to satisfy the frustrated farmers.

Understanding gender is critical for making a positive impact. Taking women into account was crucial for the Marando Bora project, whereas the women in Malawi had specific constraints for acquiring the capital and the wetlands needed to produce potatoes (Gender and seed case).

Section summary. Most interventions seek to create new delivery channels, and rarely work with informal markets. Most of the interventions were based on some information about farmer demand, but not necessarily with a rigorous understanding of seed system dynamics. Projects often ensure that the new seed is affordable, at least temporarily. Strong market demand for the ware produce is also a way of making seed affordable, and does not depend on project support. Interventions can provide information that enhances the seed system; however, the private sector (and even public projects) can oversell the virtues of their innovations.

1.3 SEED QUALITY

Seed quality is based on the concepts of (1) genetic quality (the right variety, no off types); (2) health—pests and diseases are below their threshold level; (3) physiological quality—at the right physiological age (e.g., properly stored in the case of potato and yam or fresh enough for most other RTB seed); and (4) sound physical quality (size, shape, and free of mechanical damage).

Genetic quality, varieties. An intervention has much leeway in choosing which variety to promote. A project can promote local varieties by conducting research on new technologies that enhance the performance of those varieties, and reduce the yield gap (between potential and realized yield). This is especially important for preserving local varieties in their area of origin (e.g., potatoes in Peru and Yam in Nigeria).

The project may also promote modern varieties that already existed in the system (e.g., CONPAPA in Ecuador, 3G in Kenya, or the banana cases). The intervention can champion new varieties which are the result of plant breeding—for example, the cassava cases in this book.

Genetic purity. This is a major issue in grains, but is usually less important in RTB crops because the planting material is big and off types can be easily detected and discarded. None of the case studies mention genetic purity as a constraint. However, recognizing varieties once they are detached from the mother plant (e.g., in bananas) requires careful attention to labeling.

Genetic quality, biodiversity is an issue for all RTB farmers who grow different varieties of the same crop. The integration of varietal diversity in seed systems might be an important component for managing seed degeneration, as demonstrated with foliage diseases (Garrett and Mundt 2000). Yet, RTB seed system interventions are often less diverse than what is found in farmers' fields. In this book the Cajamarca case (potato in Peru) and AYMT (Yam in Nigeria) worked in the crops' area of origin. In Peru the project tried to promote native varieties that farmers had lost. In Yam in Nigeria, the proposed seed technology was variety-neutral (it could easily be used to improve the health of native varieties). Two of the projects worked in a secondary center of biodiversity for the banana (TC and Emergency banana), where they promoted commercial varieties already being widely grown in the area.

Health. An absence of seed health is linked to rapid and devastating losses usually caused by emerging pathogens, as in the case of *Xanthomonas* wilt in banana (see the TC and Emergency banana cases), or to degeneration, in which yield and quality decrease due to pest or disease accumulation in the planting material after several cycles of asexual propagation (Thomas-Sharma et al. 2015). Some of the case studies show that farmers themselves have a concept for degeneration. They may refer to it as "tired seed" (3G potato), or "seed that has lost its power" (Gender and seed, Malawi).

Emerging pests that cause devastating losses can be excluded by quarantine. Once the pest has entered a certain area, a drastic tactic for managing it is host eradication. In the case of pathogens that cause degeneration (either emerging or endemic), Thomas-Sharma et al. (ibid.) propose managing degeneration with a combination of host-plant resistance, clean seed, and on-farm management (e.g., PS or NS, crop rotation, chemical control, etc.). The projects described in this book tried all of these tactics (see Table 15.1).

Table 15.1. Seed health constraints and management tactics

Case study	Seed health constraint	Management tactics				
		Quarantines	Host eradication	Host resistance	On-farm management	Clean seed
CONPAPA (potatoes)	Black scurf (<i>Rhizoctonia solani</i>), Andean weevil (<i>Premnotrypes vorax</i>)				Yes	Yes
Cajamarca (potatoes)	Late blight (<i>Phytophthora infestans</i>), Andean weevil					Yes
AYMT (yam)	Nematodes (<i>Scutellonema bradys</i> and <i>Meloidogyne</i> spp.), fungi (<i>Botryodiplodia</i> sp., <i>Fusarium</i> sp.), several insects			Yes	Yes	Yes
TARGET (bananas & plantains)	Sigatoka (<i>Mycosphaerella fijiensis</i> & <i>M. musicola</i>), nematodes, weevils (<i>Cosmopolites sordidus</i>), BSV (Banana Streak Virus)			Yes	Yes	Yes
Marando Bora (sweetpotato)	SPVD (sweetpotato virus disease)				Yes	Yes
Superfoods (sweetpotato)	SPVD				Yes	Yes
Three generations (3G) (potato)	Viruses: Potato leaf roll virus (PLRV), potato virus Y (PVY); bacterial wilt (<i>Ralstonia solanacearum</i>)			Yes	Yes	Yes
CLAYUCA (cassava)	Mentioned in passing					Yes
Gender and seed (potato)	Late blight, bacterial wilt, blackleg (<i>Erwinia carotovora</i>), PLRV, tuber moths (<i>Phthorimaea operculella</i>), rootknot nematodes (<i>Meloidogyne javanica</i>)			Yes	Yes	Yes
UPoCA (cassava)	CMD (cassava mosaic disease)			Yes	Yes	Yes
Tissue culture (TC) banana	Xanthomonas	Yes	Yes		Yes	Yes
Emergency banana	Xanthomonas	Yes	Yes		Yes	Yes
Great Lakes Cassava Initiative (GLCI)	Cassava mosaic disease (CMD), cassava brown streak disease (CBSD)	Yes		Yes	Yes	Yes

By far, the preferred tactic for managing seed health constraints was using clean (healthy) seed (Table 15.1). Quarantines were used to prevent emerging pathogens—for example, Kenya had imposed a ban on importing seed potato, and the UPoCA project avoided moving cassava planting material between countries in order to avoid the international transfer of diseased material. Host eradication

was tried in the Emergency banana case. Host resistance was used in the UPoCA case with cassava, and in the Ghana plantain case (TARGET), but not in the two East African banana cases, which used the clean seed approach. In at least nine of the case studies in which degeneration was a serious concern, on-farm management was an option for improving seed health, which indicates some integration between formal and informal approaches. For example, in the 3G case in Kenya, thousands of farmers were trained on how to do PS and NS to keep their seed healthy. Both sweetpotato cases also made an effort to enhance farmers' ability to keep seed healthy by growing it in net tunnels. In the Yam in Nigeria case, the project focused on strengthening farmers' capacities for managing their own seed. In other cases (e.g., CONPAPA in Ecuador), although on-farm management was mentioned, the main impact was attributed to using clean seed.

Host resistance to pests was tried in some interventions (e.g., UPoCA and GLCI for cassava and TARGET in Ghana for plantains). Because of the technicalities of plant breeding, a resistant variety is not always available. Clean seed is used especially when there is no resistant variety. The method usually involves some high technology for cleaning the seed (such as TC for bananas and sweetpotato), then multiplying early generation seed under controlled conditions (such as aeroponics for potatoes), and then having a network of multipliers at different levels to produce the final seed. The tricky part is then to keep the seed healthy in open fields while bulking up more seed. This is a special challenge for an RTB crop, all of which are slow to multiply.

Physiological age. Potato and yam seed go through a dormancy period, whereas most other RTB crops are planted from fresh material. Good storage is a way of managing physiological age (as with potato in Malawi). For seed that must simply be kept as fresh as possible, moving planting material from one place to another is also an option (e.g., taking planting material from gardens with water to dry lands at the start of the rains, as in the case of Marando Bora).

Physical quality. Size is an issue in some crops (potato) as farmers sell the bigger tubers and use the smaller ones for seed. Shape is also important because some viruses distort parts of the plant, including the seed. These two issues are mentioned as criteria for selecting seed in training guides for on-farm seed management in Kenya (Gildemacher 2007), Peru (Orrego et al. 2011), and Ecuador (Montesdeoca et al. 2012).

Section summary. Most interventions work with improved varieties, often ones that enjoy high market demand. Biodiversity is an issue especially in the center of origin or secondary center of diversification for the specific crop, but seed interventions can favor native varieties. Genetic purity is easier to manage in RTB than in grain or pulse seed, because of the larger size of RTB planting material, and because vegetative crops breed true. Seed health is linked to rapid and devastating losses or to degeneration caused by pests and diseases, and it can be managed in various ways, including quarantines, host eradication, host resistance, on-farm management, or clean seed. Physiological age is more important in RTB than for grain and pulse crops, because RTB planting material is more perishable. Physical condition (e.g., size and shape) is frequently a quality issue for RTB seed.

2. Seed Producers

This section discusses specialized seed producers: the seed growers themselves, their seed markets, their policy environment, and their seed multiplication techniques.

2.1 SPECIALIZED SEED PRODUCERS

In this book, only one project helped specialized seed producers become private enterprises (3G potato in Kenya), where commercial farms began to specialize in seed potato because of a combination of (1) newly rationalized government regulations that supported on-farm commercial seed production; (2) awareness campaigns (paid for by the project, not by the seed producers) that encouraged farmers to buy the seed; and (3) new technology (aeroponics), which is expensive and demanding but within the competency of the large farms.

Market chains. Money is a great motivator. Anthropologist Paul Sillitoe (2010) describes a people of Highland New Guinea, the Wola, who grow and eat almost nothing but sweetpotatoes. Yet the Wola cannot sell sweetpotatoes, because there is no market for them. Every HH grows its own sweetpotatoes and no outsiders drive into Wola country looking for roots to buy. When the Wola want a watch or a machete or a tin of sardines, the best way to get this prize from the outside world is by working for wages, often by migrating. If sweetpotatoes cannot be sold, there is no motivation to grow more than one's HH can eat, and there is no market for seed.

Some of the places described in this book were weakly linked to the world economy a generation or two ago. Most of the harvest went into the family cooking pot, and there was no money to buy seed. Watches and tinned sardines were hard to come by. That is changing rapidly in some places, especially the villages close to the expanding cities of Africa and Latin America, with their new agro-industries, supermarkets, and flourishing wholesale markets.

In their own way, all of the cases had a value chain (market) approach, which is a sign of progress. A few decades ago agronomists rarely thought of food markets. Two of the projects promoted seed value chains: 3G potatoes in Kenya and CONPAPA in Ecuador. Farmers are responding by growing enough potatoes to sell. These farmers now have money for seed.

Farmers in Nicaragua (CLAYUCA) are happy to grow extra cassava for the new snack-food industry, and the chip factories are willing to give the farmers seed of the new varieties the manufacturers need, because the farmers can reproduce the seed at home.

Several had food value chains integrated into seed value chains: Peruvian potatoes (Cajamarca), Nicaraguan cassava (CLAYUCA), Malawi potatoes (with its chip-maker as aeroponics seed producer—Gender and seed case), and Rwanda sweetpotato (with a biscuit-maker creating demand for OFSP—Superfood case). Some of the other cases either tried to promote food processing (e.g., making cassava flour, in UPoCA) or they based their assumptions about seed demand on a reasonable picture of market demand for the harvested crop (AYMT case on Yam in Nigeria, TC, and Emergency banana).

Section summary. Market integration is important for developing a seed system. The studies show that farmers may buy seed if they have somewhere to sell their product, especially if industry demands

a new variety. The project has to decide whether it will subsidize the planting material or sell it at full cost.

2.2 POLICY ENVIRONMENT

Aligning with government policies of the host country can be appropriate but also risky (e.g., in the case of CLAYUCA in Nicaragua, where a change in government left the project without counterpart support for several years).

It is a challenge to define appropriate levels of oversight in RTB, particularly to avoid introducing new pathogens and to reduce seed degeneration. Nearly all countries have some regulations regarding RTB seed, although enforcement may vary and may be difficult to implement. In some of the cases in this book, project staff were able to influence policy change. For example, in Ecuador, new regulations for potato QDS are based in part on the experience with CONPAPA. In Tanzania, the project supported seed inspection (in the field) by extension officers, and found that the costs were much lower than those of inspection by the plant protection officer (Marando Bora). The new potato seed system in Kenya lifted some of the restrictions on selling seed (3G seed potato).

Some of the projects in this book worked mostly with nongovernmental partners with little inclusion of regulatory agencies (TC). The interventions generally avoided taking planting material across borders, in part because of regulations that hinder such movement, although TARGET in Ghana did import some clean planting material to obtain new hybrids.

Section summary. Interventions should (usually) align with government policies. This may provide an opportunity for working with governments to rationalize RTB seed regulations, as seen with QDS.

2.3 RAPID MULTIPLICATION TECHNIQUES

RMTs (aerponics, TC, macropropagation) may fail if people do not have the skills, capital, and labor to use them. Macropropagation of banana plantlets can be done on-farm, technically, but farmers must learn multiple new tasks: paring to remove roots, boiling a water treatment to eliminate nematodes from suckers, peeling to expose axillary buds, destruction of the apical meristem to stimulate shoot development, substrate sterilization, humidity chamber management, rooting, and hardening. Failure to implement all steps may ruin the planting materials, or propagate diseased materials.

One case (Yam in Nigeria) worked specifically with a seed multiplication technique that ordinary farmers (as well as seed producers) could use on their own farm. This technique was based on previous yam seed technologies that were too labor intensive. AYMT needs a follow-up study to see whether farmers are actually adopting it (although new projects are promoting it). These examples show that on-farm seed management technologies or enhanced seed networks are viable solutions in some cases.

Aerponics was implemented in three cases: Cajamarca, 3G, and Gender and seed. It is a demanding technology, and was perhaps a poor choice for the difficult conditions of Malawi and of Cajamarca, Peru. However, aerponics was apparently a success in Kenya (3G), where large, private farms could use the technique and the seed was promoted by mass awareness campaigns for farmers.

This illustrates that a more systematic approach is needed when selecting an RNT, using technical, economic, and environmental criteria, as described by Mateus-Rodríguez et al. (2013) for aeroponics.

Section summary. Seed interventions often underestimate the difficulty of introducing a new seed multiplication technique to smallholder farmers. Interventions often fail to adapt new multiplication techniques to smallholders' reality. High-technology multiplication techniques may be profitably adapted, especially by larger farms.

3. Recommendations

3.1 TYPE OF INTERVENTIONS: JUSTIFICATION AND SCALE

Interventions that link farmers to markets for ware produce may be more successful than others. Multinational projects are definitively more difficult to implement than pilot projects. But there is a trade-off with impact. If an intervention needs to reach many farmers with a new crop variety, a multinational project may be justified. National-level projects are more appropriate for integrating seed systems with government policy and with markets. Smaller projects may do a better job at experimenting with new technology or with social innovations.

3.2 STAKEHOLDERS

It may be best to build a seed intervention on existing seed systems. But most of the projects created new networks of multipliers starting from scratch, even if this meant avoiding existing seed multipliers or distributors.

RTB crops evolved long before cities, money, and government. Yet today, markets and regulations are an important part of the environment of vegetative seed crops. Projects need to examine their often unspoken bias against existing market channels for seed, which could be an interesting research area for the future if we are aiming at better integration between formal and informal seed systems, as suggested by Thiele (1999).

As a first step, the planners of an intervention should make an explicit inventory of the main bottlenecks (of availability, access, or quality), and how those are related to the main stakeholders (using the multi-stakeholder framework for intervening in RTB seed systems) (RTB 2016).

3.3 SEED AVAILABILITY

An intervention should engage in dialogue with national and regional policymakers and regulatory bodies. Formal certification schemes alone are not able to produce sufficient seed and are often inappropriate for RTBs, which are more suited to decentralized seed production and quality assurance. Encourage policymakers to create a greater role for QDS, which can more effectively increase the quantity of improved quality of seed available to farmers.

Regulations for RTB crops often need to be relaxed. In certain situations, RTB seed is not profitable to multiply if it has to be certified. Or the system needs a more appropriate quality control, such as QDS,

where seed is produced from healthy source seed, according to quality standards and inspections adapted to local conditions.

RMTs (e.g., aeroponics and TC) are more sustainable when combined with training and capital investment. Better resourced individuals (i.e., larger-scale farmers) and organizations are often the most qualified to multiply high-quality RTB seed. Strengthening farmer-based seed conservation practices is a crucial complementary intervention to ensure availability across seasons and years.

Projects can help rural communities to link proactively with their buyers and consumers, by using participatory market chain analysis (see, e.g., Thiele et al. 2011). Market integration also helps to pull seed into the market.

Before selecting a technique (e.g., to multiply or store seed or to diagnose pests), do a literature review and see whether there are data on economic and agronomic feasibility. If not, make your assumptions explicit and discuss them with peers to prevent making the same mistakes over and over again. Projects need to do more to find solutions that fit the reality of smallholder farming.

3.4 SEED ACCESS

It is especially important to understand existing seed systems and farmers' practices when designing the delivery of seed. First, develop an in-depth understanding of existing seed systems and farmers' practices. Many or most of the farmers are women, who may have unique needs. Women and youth should be fully involved in the diagnostics of seed systems, and have assured access to training, technologies, and the resources to use them. Take into account farmers' real demand for seed.

It is important to have a good estimate of farmer demand—be realistic when doing so. Farmers may need only small amounts, especially if they can multiply the planting material themselves. Information sharing is critical for success; for example, project staff can share ideas with farmers about improved techniques for managing seed, and farmers can share ideas about their criteria for desired varieties.

3.5 SEED QUALITY

For new varieties, the intervention should identify what key stakeholders want—for example, mothers should be involved in choosing new, nutritious varieties. For market varieties, the processing companies have to be on board. But sometimes key stakeholders want different and contradictory things. Breeders may be targeting resistance to a pest that has not yet arrived, while farmers are looking for a fast-growing variety. The framework should help tease out the differences and lead to negotiated solutions.

In areas with high biodiversity, the local regulations usually do not always consider native varieties. For example, in Peru of the more than 4,000 native potato varieties, just 60 natives are registered with the government. So strictly speaking, it is illegal to sell seed of these unregistered varieties. It is important to try to modify the existing regulations so as to recognize native varieties, in countries where landraces have not been incorporated into the formal system.

Given the importance of health in RTB seed, a logical step is to identify the main emerging or endemic pests that are causing devastating losses or degeneration. A literature review and field visits are a good start. Based on this information, the intervention can define the best management tactics. In this book we mention five tactics (quarantines, host removal, host resistance, on-farm management, and use of clean seed); depending on the pest, there could be others.

When sharing varieties with poor farmers and vulnerable groups (e.g., women), be aware of the effects of disseminating varieties that are susceptible to key diseases. An intervention may face a potential conflict between host resistance and clean seed. Resistant crop varieties degenerate slowly, so there is less need for clean seed (except for accessing new varieties).

Conclusion

By using our framework, we learned that seed is usually available before the intervention, but quality may be an issue. Interventions tend to create alternative delivery systems, avoiding local markets and traders. The new seed provided by an RTB seed intervention must often be subsidized or given away if farmers are to be able to afford it. The new seed often does meet farmers' demands, even if the intervention does not start with an explicit study of the system. Genetic purity is not much of an issue in RTB crops, but seed quality is much more challenging to maintain than for true seed crops.

The framework could be used before starting to intervene in seed systems for clonally propagated crops, to see the roles and potential conflicts between stakeholders. This did not always happen in these case studies, but the interventions did do a fairly good job of linking different stakeholders in mutually beneficial ways. For example, farmers got useful new varieties from plant breeders, and farmers were linked to output markets (increasing cash flow, which allowed farmers to buy more seed). Some of the new seed multiplication techniques were appropriate for large, commercial farms. Some of the technical innovations could be used by smallholders (e.g., community cassava gardens, and PS for seed). But more must be done to see smallholders' unique needs for new technology, to involve existing seed markets in interventions, and to understand the roles of different stakeholders when proposing an intervention in an RTB seed system.

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References cited

- Badstue LB. 2006. Smallholder Seed Practices: Maize Seed Management in the Central Valleys of Oaxaca, Mexico. Thesis, Wageningen University. 327 pp.
- Bentley JW, Tripp R, Delgado de la Flor R. 2001. Liberalization of Peru's formal seed sector. *Agriculture and Human Values* 18(3):319–331.
- Coyne D. 2009. Pre-empting plant-parasitic nematode losses on banana in Africa: which species do we target? *Acta Horticulturae* 828:227–236.
- de Haan S, Núñez J, Bonierbale M, Ghislain M. 2010. Multilevel agrobiodiversity and conservation of Andean potatoes in Central Peru: Species, morphological, genetic, and spatial diversity. *Mountain Research and Development* 30(3):222–231.
- Folkema J, Ibrahim M, Wilkinson E. 2013. World Vision's resilience programming: adding value to development. ODI working paper.
- Garrett KA, Mundt CC. 2000. Host diversity can reduce potato late blight severity for focal and general patterns of primary inoculum. *Phytopathology* 90:1307–1312.
- Gibson RW, Kreuze JF 2015. Degeneration in sweetpotato due to viruses, virus-cleaned planting material and reversion: A review. *Plant Pathology* 64:1–15.
- Gildemacher P. 2007. Select the Best: Positive Selection to Improve Farm Saved Seed Potatoes. Trainers Manual. Lima: CIP.
- Kloppenborg JR. 2005. First the Seed: The Political Economy of Plant Biotechnology. Madison, WI: University of Wisconsin Press.
- Montesdeoca F, Panchi N, Pallo E, Yumisaca F, Taípe A, Mera G, Espinoza S, Andrade-Piedra J. 2012. *Producamos Nuestra Semilla de Papa de Buena Calidad: Guía Para Agricultoras y Agricultores*. Quito: CIP, INIAP.
- Orrego R, Manrique K, Quevedo M, Ortiz O. 2011. *Mejorando la Calidad de Nuestra Semilla de Papa Mediante La Selección de Las Mejores Plantas. Guía de Campo para Agricultores*. Lima: CIP.
- RTB (CGIAR Research Program on Roots, Tubers and Bananas). 2016. Multi-stakeholder framework for intervening in RTB seed systems. Lima: RTB Working Paper No. 2016-1. ISSN 2309-6586. 13 p.
- Sperling L. 2008. *When disaster strikes: A guide to assessing seed system security*. Cali, Colombia: IITA.
- Stone GD. 2007. Agricultural deskilling and the spread of genetically modified cotton in Warangal. *Current Anthropology* 48(1):67–103.
- Thiele G. 1999. Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development* 27(1):83–99.
- Thiele G, Quirós CA, Ashby J, Hareau G, Rotondo E, López G, Paz Ybarnegaray R, Oros R, Arévalo D, Bentley J eds. 2011. *Métodos participativos para la inclusión de los pequeños productores rurales*

en la innovación agropecuaria: Experiencias y alcances en la región andina 2007–2010. Lima: Programa Alianza Cambio Andino. 197 pp.

Thomas-Sharma S, Abdurahman A, Ali S, Andrade-Piedra JL, Bao S, Charkowskif AO, Crook D, Kadian M, Kromann P, Struik PC, Torrance L, Garrett KA, Forbes GA. 2015. Seed degeneration in potato: The need for an integrated seed health strategy to mitigate the problem in developing countries. *Plant Pathology* 65:3–16.

Urrea-Hernandez C, Almekinders CJM, van Dam YK. 2015. Understanding perceptions of potato seed quality among small-scale farmers in Peruvian highlands. *NJAS–Wageningen Journal of Life Sciences* 76:21–28.

Van Mele P, Bentley JW, Guéi R. 2011. *African Seed Enterprises: Sowing the Seeds of Food Security*. Wallingford, UK: CABI. 236 pp.



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