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User Guide to the Toolbox for Working with Root, Tuber and Banana Seed Systems

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OCTOBER 2020

RESEARCH PROGRAM ON Roots, Tubers and Bananas

LED BY CIP INTERNATIONAL POTATO CENTER, Bioversity International, CIAT, cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT, IITA

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Correct citation: Andrade-Piedra, J.L.; Almekinders, C.; McEwan, M.; Kilwinger, F.; Mayanga, S.; Mulugo, L.; Delaquis, E.; Garrett, K.; Omondi, B.A.; Rajendran, S.; Kumar, L.P.; Kawarazuka, N. and Thiele, G. 2020. User guide to the toolbox for working with root, tuber and banana seed systems. Lima (Peru). CGIAR Research Program on Roots, Tubers and Bananas (RTB). RTB Working Paper. No. 2020-1. Available online at: www.rtb.cgiar.org

Published by the CGIAR Research Program on Roots, Tubers and Bananas
The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a partnership collaboration led by the International Potato Center implemented jointly with the Alliance of Bioversity International and the International, the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA), and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), that includes a growing number of research and development partners. RTB brings together research on its mandate crops: bananas and plantains, cassava, potato, sweetpotato, yams, and minor roots and tubers, to improve nutrition and food security and foster greater gender equity especially among some of the world's poorest and most vulnerable populations.
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ISSN
DOI+ISBN

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADA	Austrian Development Agency
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIP	Centro Internacional de la Papa (International Potato Center)
CLAYUCA	Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca (Latin American and Caribbean Consortium for the Support of Cassava Research and Development)
CRS	Catholic Relief Services
EGS	Early generation seed
GIS	Geographic information system
ICTs	Information and communication technologies
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INA	Impact network analysis
KII	Key informant interview
M&E	Monitoring and evaluation
MEC	Means-end chain
NARS	National agricultural research system
NRI	Natural Resources Institute
R&D	Research and development
RTB	CGIAR Research Program on Roots, Tubers and Bananas
SEGSBAT	Sustainable early generation seed business analysis
SLCMV	Sri Lankan cassava mosaic virus
ST	Seed Tracker
UF	University of Florida
VPC	Vegetatively propagated crop
WTA	Willingness to accept
WTP	Willingness to pay
WUR	Wageningen University & Research

Overview

This user guide to the Toolbox for working with root, tuber and banana seed systems introduces tools to diagnose, evaluate, and improve seed systems of banana, cassava, potato, sweetpotato, and yam. As a whole, these crops are called roots, tubers and bananas, and they are crucial for food security and income generation, especially in developing countries. All of these crops are reproduced vegetatively, from roots, tubers, stems, suckers or vines. This bulky planting material is expensive to transport. Vegetative seed is perishable and (except for potatoes, yams and a few other exceptions) must be planted as fresh as possible, and it is more likely to carry pests and diseases than true seed. Besides these unique challenges, improved seed systems of root, tuber and banana crops give farmers the opportunity to boost their livelihoods by accessing better quality planting material from landraces or improved varieties that are high yielding, resistant to stresses, more nutritious or more responsive to consumer demand.

The tools in this toolbox include methods, models, approaches, and information and communication technologies (ICTs), which can be used by researchers, policy makers, and practitioners working on seed systems of root, tuber and banana crops. Section 1 of this user guide describes the importance of good planting material, key concepts of seed systems, the rationale behind the tools and the toolbox, and how they were developed. Section 2 discusses the users, purposes, and entry points for using the tools from the perspective of a seed value chain or a project cycle. Section 3 describes the Glossary of root, tuber and banana seed systems, and the 11 tools now in the toolbox: (1) multi-stakeholder framework, (2) impact network analysis (INA), (3) seed tracker, (4) integrated seed health approaches and models, (5) seed tracing, (6) small-N/exploratory case study, (7) four-square method, (8) means-end chain analysis, (9) experimental auctions, (10) seed regulatory framework analysis, and (11) sustainable early generation seed business analysis tool (SEGSBAT). Each description includes examples of questions that the tool can help answer, as well as how gender and social groups are considered. Section 4 describes the expected outcomes from using the tools, with examples of their use. Section 5, conclusions and perspectives, discusses training, backstopping and feedback, and new tools that may be included in the future. There are bibliographical references and a brief glossary of seed system terms.

This user guide is intended to be used with this Toolbox web page (under construction), where links to detailed information are available, including user guides, description sheets, research papers, and blogs for each tool.

Acknowledgments

This research was undertaken as part of, and funded by, the CGIAR Research Program on Roots, Tubers and Bananas (RTB), with support from CGIAR Fund Donors.

The following people attended workshops that helped to develop, adapt and test the tools described in this user guide (in alphabetical order): Susan Ajambo, Conny Almekinders, Kelsey Andersen, Jorge Andrade-Piedra, Elly Atieno, Ian Barker, Jeffery Bentley, Guy Blomme, Loretta Byrnes, Chris Buddenhagen, Carlo Carli, Mónica Carvajal, Danny Coyne, Wilmer Cuéllar, Erik Delaquis, Martin Dyer, Roosevelt Escobar, Joubert Fayette, Gregory Forbes, Karen Garrett, Richard Gibson, Simon Heck, John Hernandez-Nopsa, Reinhardt Howeler, Wellington Jogo, Kim Jacobsen, Mohinder Kadian, Regina Kapinga, Eldad Karamura, Nozomi Kawarazuka, Fleur Kilwinger, Enoch Kikulwe, Jan Kreuze, Peter Kromann, Peter Kulakow, P. Lava Kumar, James Legg, Yvan Mathieu, Margaret McEwan, Steven Morse, Lucy Mulugo, Israel Navarrete, Lilian Nkengla-Asi, Kwame Ogero, Richardson Okechukwu, Aman Bonaventure Omondi, Ricardo Orrego, Oscar Ortiz, Bernardo Ospina, Tom Pircher, Uta Priegnitz, Srinivasulu Rajendran, Anne Rietveld, Elmar Schulte-Geldermann, Steffen Schulz, Ali Shahid, Vanya Slavchevska, Louise Sperling, Charles Staver, Paul Struik, Graham Thiele, Sara Thomas-Sharma, Carolina Urrea-Hernández, Stephen Walsh and Yanru Xing. This user guide was edited by Jeffery Bentley.

The tools described in this user guide were created with the support of the following institutions: International Potato Center (CIP), International Institute of Tropical Agriculture (IITA), Alliance of Bioversity International and CIAT, University of Florida (UF), Wageningen University & Research (WUR), Makerere University, CLAYUCA Corporation, Catholic Relief Services (CRS), Bill and Melinda Gates Foundation (BMGF), Kansas State University (KSU), Kisima Farms, the McKnight Foundation, Natural Resources Institute (NRI), Syngenta Foundation, University of Surrey, University of Wisconsin (UW), VITROVIC S.A., Australian Centre for International Agricultural Research (ACIAR), and the Austrian Development Agency (ADA).

User Guide to the Toolbox for Working with Root, Tuber and Banana Seed Systems

SECTION 1. INTRODUCTION

SCOPE AND OBJECTIVE

This user guide explains how seed systems of banana, cassava, potato, sweetpotato, and yam—*roots, tubers, and bananas*—can be studied and improved by using tools (methods, models, approaches, and information and communication technologies [ICTs]), which are grouped into the toolbox described here. The objective is to provide an overview of how different users—researchers, policy makers, and practitioners—can use the tools to answer key questions to understand seed systems of roots, tubers, and bananas, improve them by conducting projects, and monitor and evaluate those interventions.

PROVIDING FARMERS WITH GOOD PLANTING MATERIAL

Root, tuber, and banana crops are vegetatively propagated crops (VPCs). Farmers use roots, tubers, stems, suckers or vines as planting material, commonly referred to as *seed*. VPCs are unlike grain and legume crops that are planted with true, botanical or sexual seeds, which is almost always dry. Vegetative planting material is fresh and moist, rendering it bulky, perishable, more prone to carrying pests and pathogens and multiplication rates are low (demanding large amounts of planting material for small areas of land). But vegetative propagation allows the crop to multiply true-to-type. Because planting material is genetically identical to the parent plant, each generation is cloned from the previous one. Therefore, the breeding, multiplication and distribution of root, tuber and banana planting material is quite different from that of true seed crops like grains, pulses and many vegetables.

Good planting material is healthy, in optimal physiological condition, without physical damage, and of the preferred variety. Access to such material is important for many reasons. First, roots, tubers, stems, suckers or vines are the start of a new crop and if the planting material is of poor quality, the crop will be disappointing, and the yield will be low. Second, availability and access to good planting material are key to conserving valuable landraces and to disseminating improved varieties with novel genetic traits such as drought or disease resistance, and higher nutritional value. Projects that aim to improve yields, nutrition, market access, pest and disease management, for example, depend heavily on ensuring good planting material for both women and men farmers from various socio-economic backgrounds.

Seed system. A good seed system makes sure that both women and men farmers get the best possible seed. ‘Seed system’ can be defined in different ways. A farm, crop, locality, region, or nation can all be said to have a seed system. This user guide defines a seed system as: ‘the network of seed users, the private food sector, extensionists, farmer organizations, specialized seed producers, traders, researchers, policymakers and other stakeholders involved in providing, managing, replacing, and distributing the seed of a particular crop in a certain area’ (adapted from Bentley et al. 2018).

A well-functioning seed system. Whether a seed system is well-functioning or not depends on the context: good for whom and from whose perspective? A civil servant who is responsible for national food security and for affordable food prices in cities will have a different view from a breeder, a seed producer, an NGO representative, a female farmer, or a male farmer. But a well-functioning seed system ensures that enough good planting material of demanded varieties is available at the right time, and at affordable prices. A well-functioning seed system avoids spreading pathogens and pests, and helps farmers adapt to local and global challenges, such as climate change, while considering specific constraints, complying with national seed regulations, and providing enabling conditions for disadvantaged social groups such as women, youth and ethnic minorities.

Informal seed systems and farmers practices. Seed systems in developed countries are tightly regulated by government agencies, farmers' associations, and commercial seed companies. This structure, often called a 'formal seed system,' sets criteria and guidelines for authorizing seed production by qualified seed producers, while discouraging, and sometimes punishing, unauthorized seed production. In many developing countries, few crops have well-defined, formal seed systems; this is especially true for root, tuber and banana crops. However, even where there is no formal seed system, farmers plant and harvest by virtue of an informal seed system, not regulated by the government, and often difficult to see or understand. Many farmers, especially women, select seed from their own harvest, sometimes exchanging planting material with neighbors or traders. Informal seed systems are often the best option, providing fresh, affordable, local seed to farmers with limited resources.

WHY A TOOLBOX FOR ROOT, TUBER AND BANANA SEED SYSTEMS?

Researchers, policy makers, and practitioners working on research and development (R&D) deal with complex seed systems, most of them informal. Productivity is low in part due to poor planting material and because smallholders have limited access to varieties with novel genetic traits, including improved varieties. Donors and development agencies try to improve these seed systems, often by trying to make them formal. This includes setting up complex schemes for breeding, producing and distributing high-quality planting material of improved varieties. Quality assurance may vary from full certification to quality declared seed. In a few cases, informal systems are improved by the project, but most seed system support initiatives overlook informal systems.

The toolbox for working with root, tuber and banana seed systems is aimed at *understanding and supporting seed system development*, that is, increasing the availability, access, and quality of planting material of improved varieties and landraces. This is usually done through projects, or similar interventions, that can run from a couple of years to a decade or longer. Since informal systems are in place before the project, it is crucial to understand them to design meaningful interventions. Such projects can build on, replace, or modify the existing informal seed practices of traders, farmers from various socio-economic backgrounds, and other seed value chain actors. These projects should aim for gender and social equity by carefully exploring constraints, perceptions, and preferences of disadvantaged social groups, and providing enabling conditions for them.

WHO DEVELOPED THE TOOLS AND THE TOOLBOX, AND HOW

The tools were developed by a multi-disciplinary team of more than 50 scientists and practitioners from the CGIAR Research Program on Roots, Tubers and Bananas (RTB) from 10 countries[1], and six international agricultural research organizations: International Potato Center (CIP), International Institute of Tropical Agriculture (IITA), Alliance of Bioversity International and CIAT, University of Florida (UF), Wageningen University & Research (WUR), and Makerere University. This group included experts in different fields: agricultural technology development, plant breeding, anthropology, economics, gender analysis, entomology,

[1] Canada, Colombia, Ecuador, India, Kenya, Netherlands, Peru, Uganda, UK, USA.

and plant pathology. Activities to produce the tools started in December 2012 and included: design and development of the tools (often as part of PhD programs), and activities to validate the tools, usually in collaboration with national agricultural research institutes, universities, and regulatory agencies in East Africa (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda), Southern Africa (Mozambique), West Africa (Nigeria), Asia (Cambodia, India, Georgia, Laos, Vietnam), and Latin America (Colombia, Ecuador, Nicaragua, Peru).

Most of the tools were adapted from other crops or from other fields of study. For example, the multi-stakeholder framework is an adaptation of the seed system security assessment (Remington et al. 2002; Sperling 2008). The means-end chain analysis comes from marketing and consumer studies. The four-square method was originally developed for priority setting in landrace conservation.

Since roots, tubers and bananas are all vegetatively propagated, they share similarities, and the tools have usually been developed for one crop and then adapted for the others. For example, Seed Tracker, specifically developed for cassava seed, is now being used for yam and for sweetpotato.

All of these tools are responsive to gender and to different social groups of farmers. Gender intersects with other social characteristics, such as age, ethnicity and education. All of the tools described here integrate gender responsiveness as much as possible to enable researchers to explore different interests, preferences, access and constraints for different genders and social groups.

For a tool to be included in this toolbox, it must have at least one peer-reviewed scientific publication describing how it is used and how it was developed or adapted from an existing tool.

SECTION 2. TOOLS, USERS, PURPOSES, ENTRY POINTS

WHAT IS A TOOL?

In this toolbox, a tool is defined as a 'method, model, approach, or ICT used to study, diagnose, evaluate, and improve a root, tuber or banana seed system'. The toolbox contains a detailed glossary based on an expert review of the literature, and 11 tools (Table 1), but new ones may be added. A separate, brief glossary is provided at this end of the user guide to give short definitions for some of the key terms in the toolbox (Annex 1).

Table 1. Toolbox for seed systems of roots, tubers, and bananas.

No.	Tool name	Purpose
1	Multi-stakeholder framework	Identify stakeholders, coordination breakdowns, bottlenecks. Rapid assessment of seed availability, access, and quality
2	Impact network analysis (INA)	Evaluate the likely outcomes for the current system, and for potential interventions in it, in scenario analyses
3	Seed tracker	Organize information to enable quality seed production, certification, market linkages and to integrate the seed value chain
4	Integrated seed health approaches and models	Evaluate how a scenario for potential use of formal seed, disease resistance, and on-farm management are likely to affect crop health
5	Seed tracing	Map parts of the seed system such as volume of seed distributed, transaction types or types of varieties
6	Small-N/exploratory case study	Understand farmers' use of seed
7	Four-square method	Characterize seed and variety diversity and use
8	Means-end chain analysis	Understand farmers' motivations for preferring particular seed types and sources, and the expected benefits
9	Experimental auctions	Elicit individual's willingness to pay (WTP) and willingness to accept (WTA) seed traded in the market
10	Seed regulatory framework analysis	Analyze seed regulatory frameworks and implications for vegetatively propagated crops from different stakeholder perspectives
11	Sustainable early generation seed business analysis tool (SEGSBAT)	Prepare a business plan and analyze the financial sustainability of a seed enterprise
	Glossary of Root, Tuber and Banana Seed Systems	Cites published literature to define and explain important terms in seed systems research

USERS AND PURPOSES

Each tool has specific purposes as described in Table 1. There are three main groups of purposes: (1) for diagnosis and analysis, (2) for strategic intervention and planning, and (3) for monitoring and evaluation. These purposes are associated with different users of the tools and with different kinds of information that the tools provide:

1) researchers **studying seed systems** or parts of them,

2) policy makers **developing, strengthening, and supporting seed systems**, and

3) practitioners who **design**, **monitor, and evaluate seed system projects**.

Although the users may have different objectives, a tool can simultaneously serve more than one purpose and user: all need to understand the seed system (Table 2). Asking for a good diagnosis or evaluation is a request for a study of what works and does not work in a seed system in order to define an objective and design a project. Asking for the impact of a project is like asking how a seed system has changed since the start of the intervention. Good monitoring and evaluation (M&E) of changes in a seed system needs good data collection and interpretation. M&E is, therefore, like a scientific study carried out by a researcher, generating knowledge on how a seed system works, who benefits and who is left out.

Table 2. Users of the toolbox may have different interests, but they all need to understand the seed system or part of it.

The researcher may be interested in:	The policy maker may be interested in:	The practitioner may want to know:
What influences women and men farmers' choice between certified and their own farm-saved seed?	Why women and men farmers do not use certified seed?	How has the use of certified seed changed since the start of the project? Has it changed differently for women vs for men?

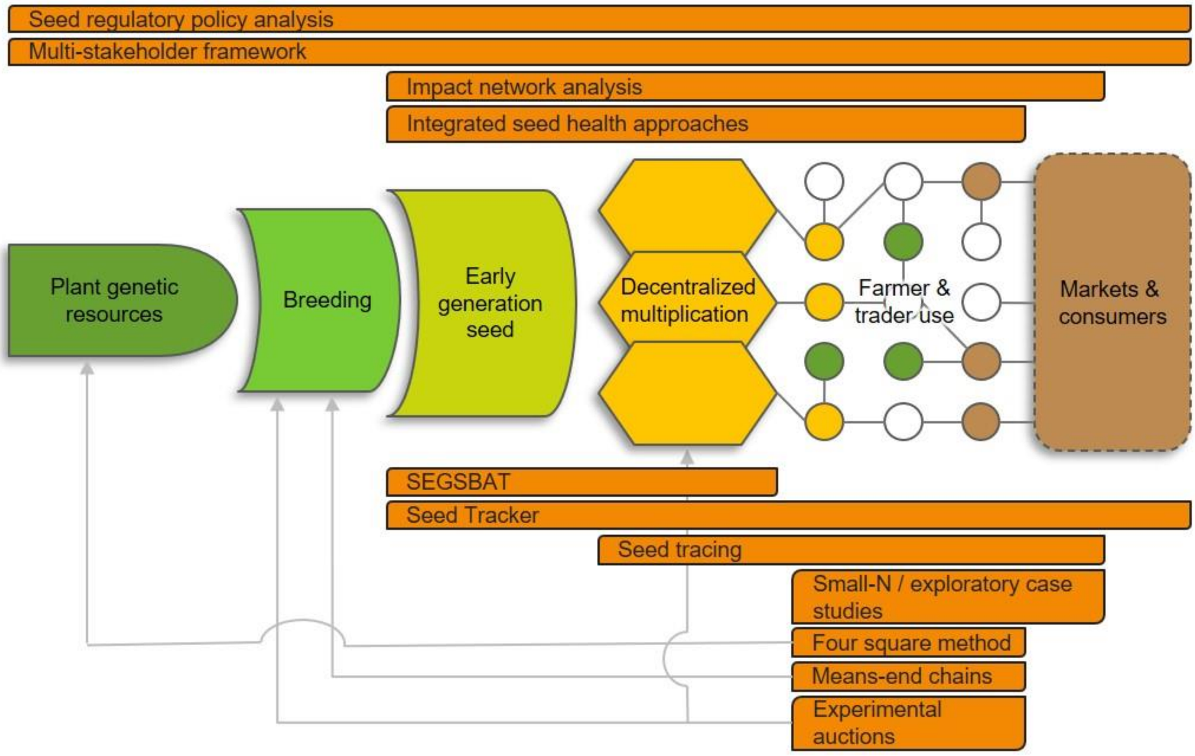
WHICH TOOL TO USE?

To visualize these different interests and questions, and to select the right tool, the toolbox has two entry points: the seed system and the project cycle.

THE SEED SYSTEM AS ENTRY POINT

One can visualize a seed system in different ways. Figure 1 presents the seed system as a seed value chain, with a schematic representation of all 11 tools. It shows how the tools provide information on one or more segments of the seed value chain. Because a functional seed value chain requires that all segments operate well, integrative tools are also required to locate the strengths and weaknesses. Examples of questions that can be answered by the tools are described in Section 3, at the end of each tool description.

Figure 1. Schematic representation of a seed system (*). The tools that can be used to study or improve different components of a seed system are shown in brown rectangles.



(*) A seed system, shown as a seed value chain, considers the pool of plant genetic resources (in specialized collections and in farmers' fields) as the starting point for breeding improved varieties. The best varieties are multiplied to provide high quality, early generation seed in strategic volumes. Decentralized multiplication by seed producers produces seed to sell to farmers, who may also select seed from their own harvest and exchange it with others in the informal seed system.

THE PROJECT CYCLE AS ENTRY POINT

A seed system project usually includes several phases: diagnosis, design, implementation, monitoring, and scenario analysis (Figure 2). Each phase may require different types of information. The tools presented in Table 1 can play a role at different moments in the project cycle. To follow change through diagnosis, design, implementation and monitoring purposes, similar information is collected periodically. For scenario analysis, a modelling approach is usually followed.

Figure 2. Schematic representation of a project cycle. Numbers in squares refer to the tools that can be used in different stages.

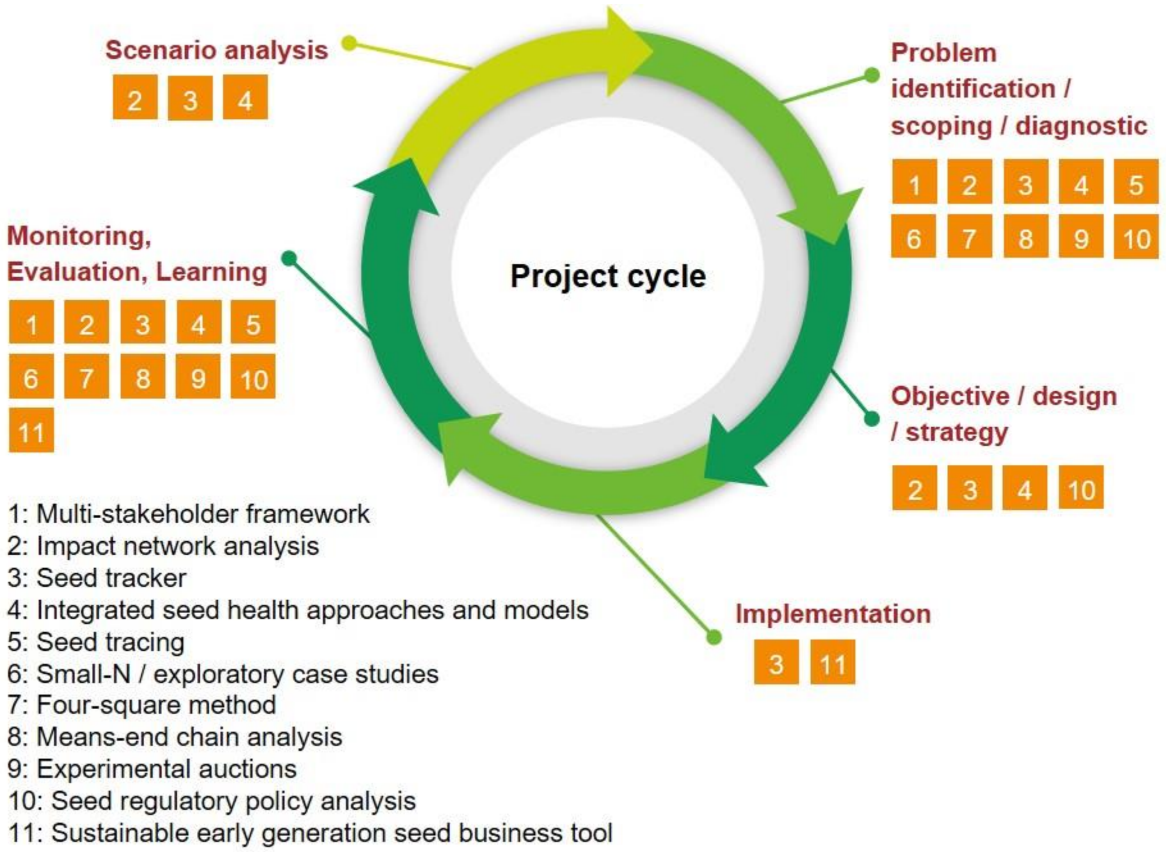


Table 3 shows how the same tool can be applied for different purposes: diagnosis, design, monitoring, and scenario analysis. The questions are framed differently according to the stage on the project cycle.

Table 3. Examples of questions that can be asked with the tool *integrated seed health approaches and models* in different stages of a project.

Stage	Question
Diagnosis	What is the degeneration rate of on-farm saved seed?
Design	How often should farmers buy certified seed?
Monitoring	How has the quality of farm-saved seed improved with the periodic use of certified seed?
Scenario analysis	How do different combinations of certified seed, host resistance, and on-farm seed management affect the degeneration rate of on-farm saved seed?

RESOURCES

Another consideration for using the tools is the availability of resources: time, money, labor, and expertise. Some tools require specialized knowledge and others are easier to apply. Extensive data collection usually increases costs, and the time needed to process and analyze the data. These considerations are taken into account in the tool description sheets available on the web site described below.

SECTION 3. DESCRIPTION OF THE TOOLS

Detailed information for each tool is provided in this Toolbox web page (under construction) with links to:

- A tool description sheet, for a quick overview of the tool, including references to literature, and other resources
- A user guide, with procedures on how to use the tool
- A peer-reviewed paper that describes how the tool is used and how it was developed, or adapted from an existing tool
- And, in some cases, a blog and other communication materials.

The tools are described below, along with examples of questions that each one can address.

1. MULTI-STAKEHOLDER FRAMEWORK

The multi-stakeholder framework gives researchers, policy makers, and practitioners a quick overview of root, tuber and banana seed systems. The framework is a table, with rows of stakeholders (seed producers, seed traders, extensionists, etc.) and columns of seed system functions (availability of seed, access, and quality). It is ideally applied during workshops and field visits as a first step towards understanding a seed system, plan or monitor a project, or evaluate one. When used before a project starts or to analyze a seed system, the framework helps to identify stakeholders, bottlenecks, and key actions for the upcoming project. When used to monitor or evaluate a project, the framework can help to document the roles of stakeholders in relation to seed access, availability and quality, coordination breakdowns between actors, and to build a stronger evidence base for future interventions. The framework provides an opportunity to differentiate access and availability of seed and varieties for different types of farmers, including males and females. The results obtained with the framework usually need to be complemented with more in-depth studies done with other tools.

Questions that can be addressed with the multi-stakeholder framework: Who are the specific stakeholders of a seed system? What is their perspective regarding seed availability, access, and quality? How do men and women farmers differ in their access to quality seed? What coordination breakdowns occur among stakeholders and how can these be resolved?

2. IMPACT NETWORK ANALYSIS (INA)

Impact network analysis (INA) is a tool for evaluating the likely outcomes of a current or potential seed system project. These results support decision-making by researchers, policy makers, and practitioners. Outcomes can be defined in terms of important features including the potential spread of disease through the system, likely adoption of new varieties in the region, and how well the system serves different categories of stakeholders. INA includes an R package that simulates outcomes for different scenarios defined by the user. Direct users would be familiar with R applications and would collaborate with indirect users. The scenarios are defined with data about seed systems gained from using other tools in the toolbox (such as seed tracing) or from other data sources. INA can be applied during project development to help make decisions and to identify information gaps for further study. INA can use disaggregated data on male and female farmers, youth and elders, or between occupational groups (such as seed producers vs traders). Intervention scenarios might include surveillance for a seedborne disease, subsidies to support adoption of new varieties, or training to promote new techniques.

Questions that can be addressed with impact network analysis: What types of interventions are likely to lead to wider adoption of a new variety? What are the best strategies for managing a disease in the seed system? What subsidies would benefit youth or women?

3. SEED TRACKER (ST)

The Seed Tracker (ST) is an ICT tool that digitally links seed value chain actors, tracks seed production, and organizes information. The ST provides digital data collection tools (usable on any internet-enabled device with an Android operating system). It offers secure individual and group accounts, and a database with analytics and geographic information system (GIS) tools. The ST covers all stages of the seed value chain and the needs of stakeholders: researchers, extensionists, regulators, seed producers, traders, service providers, and farmers. It supports seed production planning, seed traceability, seed inventory management, and quality assurance. The Seed Tracker allows regulatory authorities to monitor the production of certified seed and provides real-time information exchange between seed producers and regulators. It is also a business tool that helps to link seed producers with customers. It offers real-time information on seed production by seed class, variety, volume, and location. The ST can be customized to fit different crops, national seed regulations, and user-defined needs. ST has the potential to map gender disaggregated information.

Questions that can be addressed with the Seed Tracker: The ST was originally conceived for pragmatic, individual purposes, so that seed producers could: Where do I find customers? And, how can I certify my seed online? However, the seed tracker can also be used to ask system-level questions like: What are the current trends in seed production and certification? Where and who are the seed producers, customers, varieties grown, volumes and seed production fields?

4. INTEGRATED SEED HEALTH APPROACHES AND MODELS

Integrated seed health approaches and models provide a framework for combining three key seed health management components: clean seed, disease resistant varieties, and on-farm management. Over-reliance on any one component tends to be less effective than strategic combinations of all three. Seed health models, in particular the R package seedHealth, support consideration of integrated seed health approaches by evaluating scenarios for combining these three components. These results support training and decision-making by researchers, policy makers, and practitioners. In an online interface for training, the seedHealth package illustrates the likely outcomes from changing the three components. Direct users would be familiar with R applications, while indirect users would collaborate with the direct users. The online interface is user friendly, even for those who are not familiar with R. The seedHealth package can also be used to evaluate the likely disease and yield outcomes for specific systems and user groups (e.g., gender or age groups), when sufficient data are available about seed degeneration rates and responses. The seedHealth package can be used for decision-support modelling by users who can develop or access estimates of seed degeneration rates for their systems.

Questions that can be addressed with integrated seed health approaches and models: What combination of clean seed, disease resistance, and on-farm management will be best for a particular location? How frequently should disease-free seed be purchased? If male and female farmers have different seed management practices, how does that affect degeneration and associated yields?

5. SEED TRACING

Seed tracing can be used to map seed flows, especially as farmers multiply new varieties and distribute them in the informal seed system. The data set can form the basis of an impact network analysis (INA, see above): it forms a 'minimum data set.' Mapping the seed flows helps to understand germplasm distribution, conservation, and the spread of seedborne pathogens in a seed system. A network analysis highlights social dimensions of a seed system. For example, it can show how seed access and exchange depend on gender or on household wealth. It can also reveal which farmers have better access to formal seed. When tracing seed (through snowball sampling), data can be collected on transactions between actors, including volumes, quality and prices. The transactions form the links or edges in the network analysis and the nodes represent the actors, such as breeders, seed multipliers and farmers. Gender, wealth, location and other information can be collected from these actors, depending on the research question.

Questions that can be addressed with seed tracing. How is a new variety spreading from farmer to farmer? How do men and women share seed in different ways? What does that mean for effective introduction of quality planting material?

6. SMALL-N/EXPLORATORY CASE STUDY

The small N/exploratory case study collects data to focus on several topics, such as getting a first understanding of how farmers use and handle their seed. A small N-survey is exploratory and uses quantitative and quantitative data. It does not claim to be representative; it is more oriented towards a broad description than towards statistically significant differences and correlations. Data is usually collected with a survey form with a modest number of open-ended and closed questions; it takes about an hour or 90 minutes to complete with each farmer. There is also space to include other information volunteered by the interviewees. To identify patterns of seed use during a first reconnaissance, it is important to strategically sample different groups, such as farmers vs traders, smallholders vs large farmers, male vs female farmers. A study may require 12 to 15 surveys per type of farmer and 35 to 50 farmers per community. There is additional power when comparing case studies, for example comparing different communities.

Questions that can be addressed with small-N/Exploratory case study. Which farmers save their own seed and which ones obtain it off-farm? Where do farmers get seed when they do not use their own? What seed and varieties do large vs smallholders use? What payments and exchanges do male farmers vs female farmers use? How does seed use of older farmers differ from that of youth?

7. FOUR-SQUARE METHOD

The four-square method originally meant identifying a community's common, unique and endangered crop varieties for genetic conservation. For vegetative seed, the method can generate an inventory of varieties grown in a particular place and discuss their importance with farmers. Such information helps to identify seed interventions needed to conserve crop varieties and to highlight desirable traits in new varieties. The four-square method plots responses in two dimensions (popularity and scale) to form four cells into which seed and crop varieties are positioned: Cell 1) varieties grown by many farmers on a large area, Cell 2) those grown by many farmers on a small area, Cell 3) varieties grown by a few farmers on a large area and Cell 4) those grown by few farmers on a small area. The method is mainly applied as a first step to understand varieties grown in a community and why people plant them. The method is usually used in focus group discussions (FGDs) which can be conducted separately for different social groups (gender, age, social status etc.) to capture differentiated perspectives and experiences. The results can help to identify entry points for further research. It can also complement a small N/exploratory case study.

Questions that can be addressed with the four-square method. What local and improved varieties do farmers grow? What do they use the different varieties for? What can farmers tell about their varieties? How does the knowledge and experience of male farmers differ from that of females? What is the value of local and improved varieties, according to young farmers? What is the impact of seed system interventions on varietal diversity?

8. MEANS-END CHAIN (MEC) ANALYSIS

Means-end chain (MEC) analysis is an approach from the field of consumer studies. Its attractiveness is the freedom it gives to respondents to select and verbalize their own constructs to evaluate a product or service.

The means-end chain interviews consist of two parts: (1) the attribute elicitation and (2) the laddering. The elicitation technique consists of a triadic sorting based on Kelly's repertory grid. Typically, the farmers or traders are shown three fairly similar products or services, which they have to sort by similarities and differences. These personally relevant constructs are then linked to the interviewees' own goals via laddering interviews in which the interviewer only asks "which one do you prefer?" and "why is this important to you?" By showing the interviewees the actual planting material, the farmers may come up with characteristics or motivations that researchers could not have imagined as important. The approach was applied to capture farmers' perceptions of formal and informal sources of seed potato in Peru and banana planting material in Uganda. A MEC study requires about 40 interviews, or fewer when the answers are very similar. One can compare the responses of male and female farmers or better off and poor farmers, for example. Some training is needed, especially in the recording and analysis of the data.

Questions that can be addressed with means-end chain analysis. What variety characteristics do farmers appreciate and why? Where do farmers prefer to source their seed and why? Do male and female farmers prefer the same variety characteristics and if so, is it for the same reasons?

9. EXPERIMENTAL AUCTIONS

Experimental auctions have become a popular research method because they elicit a value for a person's real willingness to pay (WTP) and willingness to adopt (WTA). This real value is only expressed when auctions are well organized and the bidding for the product resembles a real-life situation. Economists suggest various ways to organize the bidding and the payment. Food scientists have used auctions to determine preferences and market values for new food products. This mechanism is relatively new for root, tuber and banana crops, and for seeds and varieties in general, but a growing number of studies are using this mechanism. They provide good opportunities to compare the value given to seeds, varieties or variety traits by different social groups, i.e. men and women. A WTP study using existing validated auction and bidding mechanisms is expensive.

Questions that can be addressed with experimental auctions. What is the real market value for seed? What is the difference in the real price that male and female farmers are willing to pay? What is the relative WTP between seeds of different characteristics, such as variety, source, quality level, and labelling?

10. SEED REGULATORY FRAMEWORK ANALYSIS

This tool provides actionable evidence on policy and investment options to accelerate seed system and market development in countries where vegetatively propagated crops (VPCs) are important to food security and agricultural development. The users of the tool are agricultural researchers, and policy analysts. The tool consists of a series of checklists for key informant interviews (KII) to be used with different seed system stakeholders e.g. plant breeders, public regulators of VPC planting materials, industry experts, entrepreneurs, traders, seed producers, seed importers, NGOs, or other stakeholders, including farmers and leaders of their associations. The interviews ask about gender differences in perceptions on use and implications of seed regulations. Key informant interviews should be complemented by literature review, secondary data and document analysis.

Questions that can be addressed with the seed regulatory framework analysis. What types of public policies and regulations are in place for the subject crops in a country? How are these policies and regulations implemented? What type of quality assurance is cost effective to increase access, availability, and quality of planting material? How can access to quality seed by women farmers be improved?

11. SUSTAINABLE EARLY GENERATION SEED BUSINESS ANALYSIS TOOL (SEGSBAT)

This tool helps to analyze financial performance of early generation seed (EGS) businesses run by specialized seed producers, such as NARS and private companies. EGS include *in vitro* plants, pre-basic seed, and basic seed. The supply of EGS is often a bottleneck to improving formal seed systems. SEGSBAT measures financial sustainability based on six steps: (1) identify the minimum production capacity for each stage of EGS production to meet the minimum sales targets, (2) measure the total recurrent costs of production for the final product, (3) formulate pricing strategies based on type of customer and time of order, (4) calculate funds, such as revolving funds, needed to meet total recurrent cost, (5) estimate the net cash flow based on actual sales and (6) review and update the production plan each season to track actual performance of the seed business. This tool can be used by anyone familiar with Microsoft Excel. This tool does not perform financial feasibility analysis, which includes net present values, internal rate of return, and sensitivity analysis of the business. Gender plays no obvious role in the application of the tool or the use of the resulting information.

Questions that can be addressed with SEGSBAT. What is an accurate cost of EGS production? How to determine the price of EGS products and formulate a pricing strategy for EGS products to attract more customers? Are there production inefficiencies that can be streamlined to make EGS more profitable for suppliers?

GLOSSARY

A glossary is especially important for a topic like seed systems, which brings together experts from many different fields of biology, agronomy and social science. This detailed glossary is based on a literature review of peer-reviewed publications, citing the texts and providing the references, so that readers can get a quick overview of the technical language of seed systems, while also being able to consult the original literature for a broader context.

Questions that can be addressed with the glossary. What is the difference between “quality” seed and “quality declared seed?” I need to start a literature review (for my thesis, for a course I am teaching, for a paper I am writing), where can I find some solid references to get started?

SECTION 4. EXPERIENCES FROM USING THE TOOLS

This section describes the expected outcomes from using the tools, and then some examples of results from using the tools in banana, cassava, potato, sweetpotato, and yam.

POTENTIAL OUTCOMES FROM USING THE TOOLS AND THE TOOLBOX

There are three expected outcomes. The first is at the scientific level: ***seed systems of root, tuber and banana crops better understood***. Various biophysical and socio-economic factors affect seed systems and the tools help to disentangle the complex relationships among them and predict potential scenarios to face global challenges, such as global warming, and the feminization of agriculture.

The second outcome is at the project level: ***interventions better designed, conducted and evaluated***, including a stronger focus on equity and gender. Ideally, an intervention is designed by collecting and analyzing data to understand the existing seed system in a certain place, and by using models to create scenarios to answer key questions that will inform the design of the intervention. However, in practice, specialists face tight schedules to design interventions, so they have to make educated guesses with many assumptions, usually implicit. Several of the tools help to collect and analyze data or use models to design robust interventions based on scientific information. Other tools obtain quick estimates of key variables and make assumptions explicit. Once an intervention is designed, other tools can be used to improve its implementation and evaluation.

The third expected outcome is at the policy level: ***allocation of resources informed by scientific evidence***. Most agricultural interventions in developing countries include strong seed system components. However, where to allocate the resources is usually a key concern for donors and policy makers. The tools presented here can help to allocate resources based on scientific evidence. For example, to manage seed degeneration for poor farmers in the long run, it might be more profitable to invest in breeding resistant varieties than in complex systems for delivering clean seed to farmers, as evaluated by the seedHealth model.

EXAMPLES OF RESULTS FROM USING THE TOOLS

The following five examples, one for each major crop of interest to RTB, describe where the tools have been used and their potential to better understand and improve seed systems:

Potatoes are the 'second bread' in the Republic of Georgia. However, yield is 8.9 to 12 tons per ha, while the potential yield can be as much as 50 tons per ha. One bottleneck for improving potato yield is the low quality of planting material. Potato farmers save tubers from the previous harvest to plant the next season. This practice leads to seed degeneration, because pathogens, such as viruses and *Synchytrium endobioticum* (the causal agent of potato wart), accumulate in the seed tubers, forcing yields down over time. With the support of the Austrian Development Agency (ADA), CIP, UF, and local partners designed an intervention to improve the quality of planting material (https://ishpotato.cipotato.org/) and a national plan for improving seed potato (CIP 2019), based on the integrated seed health approach (Thomas-Sharma et al. 2015) (tool 3, Table 1). Results from this intervention include the adoption by hundreds of farmers of positive selection, a simple technique for selecting the best seed tubers; the identification of three potato clones with resistance to viruses to be released as varieties; and the adaptation of international standards for seed certification to Georgian conditions. Similarly, using impact network analysis (tool 2, Table 1) the study team modelled scenarios for spread for *S. endobioticum*, as part of a risk assessment analysis, and identified areas where the pathogen needs to be monitored carefully to prevent major losses (Andersen et al. 2020).

Cassava is one of the most important cash crops in Southeast Asia. The crop's starchy roots are widely produced by smallholders in Cambodia, Laos, Vietnam, Thailand, Indonesia, and the Philippines, supplying multi-billion-dollar value chains. But despite its size and economic importance, the industry remains vulnerable to invasion by yield-limiting pests and diseases. In 2017, Sri Lankan cassava mosaic virus (SLCMV) was reported in Cambodia. Southeast Asia lacks resistant varieties, and the disease quickly spread with the aid of whitefly vectors and infected planting stems (Minato et al. 2019). Response was especially hampered by the absence of systematic knowledge of cassava seed networks. With a grant from the Australian Center for International Agricultural Research (ACIAR), the International Center for Tropical Agriculture (CIAT) led a study with WUR, UF, and national partners in Cambodia, Vietnam, and China to understand the use and movement of cassava seed, and to model likely spread and the impact of mitigation interventions. The approach used a combination of seed tracing (tool 5, Table 1) to map existing plant material exchange networks (Delaquis et al. 2018) and impact network analysis (tool 2, Table 1) to construct epidemiological models combining both environmental parameters and seed exchange networks to model spread scenarios (publication planned for 2020). The results of this work have led to a large new ACIAR research project on SLCMV response, and have been presented at stakeholder workshops and meetings of the regional taskforces for SLCMV, providing regional government representatives and cassava value chain stakeholders with the first ever regional data on SLCMV and seed exchange and scenario analyses for planning interventions.

In **sweetpotato**, the multi-stakeholder framework (tool 1, Table 1) was used as part of a post intervention review and learning workshop of the Marando Bora (Better Vines) project implemented in Lake Zone, Tanzania

(Ogero et al. 2015). The project trained decentralized vine multipliers (DVMs) to multiply planting material of improved varieties and distribute it through a subsidized voucher system. The multi-stakeholder framework allowed a systematic reflection from different stakeholder perspectives on the successes and challenges to improving the availability, access and quality of sweetpotato planting material to different types of farmers. Several challenges were highlighted: some varieties were susceptible to sweetpotato virus diseases; there was insufficient knowledge on seed degeneration and it was not clear when farmers should replace their planting material. These issues were subsequently explored in a follow up project, Kinga Marando (Protecting Vines), which introduced an innovative disease management technology using net tunnels to protect planting material from insects. Seed health models (tool 4, Table 1) were then used to assess seed degeneration for two preferred varieties, with and without nets. The findings from this research have been used to recommend the number of seasons farmers can re-use planting materials before reaching a potential economic threshold of 40% yield loss (Ogero et al. 2019).

The use of Seed Tracker (tool 3, Table 1) on **yam** in Nigeria illustrates the advantages of applying ICTs for data collection in the real-time tracking of seed yam production (Ouma et al. 2019). Seed yam data in Nigeria is predominantly collected using field notebooks, later entered into a Microsoft Access sheet. The weaknesses of these data systems include delayed feedback and the lack of data upon demand, hampering tracking of seed at various stages of crop production and management. The study gave data collectors a pre-installed Seed Tracker (ST) app for use on an Android device. This app improved efficiency, speed, and convenience in data collection and visualization, showing that the ST can be used in crop management and research, not just with seed. Receiving useful, rapid feedback was both an incentive for farmers to provide quality data and a rationale on which to base their management decisions to boost yields. Stakeholders were able to visualize trends in yam production and marketing.

In the case of **banana**, the four-square method was used in Burundi to assess how banana diversity was influenced by the invasive banana bunchy top disease and by the seed system interventions used to control it (Simbare et al. 2020). This enabled a discussion with farmers about the changes in the diversity of the East African Highland banana group, which was important because farmers are seed stakeholders and custodians of on-farm diversity. Farmers could also anticipate the eventual penetration of varieties introduced via tissue culture interventions. This study revealed the need to include a conservation objective in seed system interventions for bananas in places that are centers of secondary diversity, thus providing a strong case for alternative approaches to seed quality assurance in these areas. The data from these studies also formed the basis for an ongoing network impact study of the banana seed systems to reveal the interactions of coexisting seed acquisition systems. The study found that a blend of formal and informal approaches is required to develop the banana seed system to meet the multiple needs of households and to support them in improving productivity and dealing with emerging challenges.

SECTION 5. CONCLUSIONS AND PERSPECTIVES

The toolbox is made up of 11 tools (methods, models, approaches, and ICTs) and a glossary that can be used by researchers, policy makers, and practitioners to diagnose, evaluate, and improve seed systems of banana, cassava, potato, sweetpotato, and yam. The tools and the toolbox are the result of the combined effort of more than 50 scientists from different technical and scientific backgrounds working since 2012. Depending on their interests and questions, researchers, policy makers, and practitioners can select a tool from the perspective of a seed value chain (from plant genetic resources to markets and consumers) or a project cycle (from diagnostics to scenario analysis). The expected outcomes from using the tools include better understanding of root, tuber and banana seed systems, improved design and evaluation of interventions, and the allocation of resources based on scientific evidence. Several of these outcomes are described in examples provided for potato in Georgia, cassava in Southeast Asia, sweetpotato in Tanzania, yam in Nigeria, and banana in Burundi and Cameroon.

This user guide is a first attempt to provide training material for users on how to use the tools. This guide will be complemented with courses, webinars and other methods. However, you can contact the research teams that have developed the tools (contact information is available in the Toolbox web page, under construction) to ask for backstopping and, ideally, for collaboration and joint projects. RTB welcomes your feedback on how the tools have been used and how they performed, in order to continue improving them.

The authors envision the toolbox as a living initiative that will evolve over time. Figure 1 shows that there are components in a seed value chain that are not being addressed by the current tools. For example, tools are needed to help design strategies to disseminate improved varieties, or to help select rapid multiplication techniques to produce early generation seed. New tools will be added to cover these gaps in the future.

REFERENCES

See the tool description sheets for additional references.

Almekinders, C., Walsh, S., Jacobsen, K., Andrade-Piedra, J., McEwan M., de Haan, S., Kumar, L.P, & Staver C. (2019). Why interventions in the seed systems of roots, tubers and bananas crops do not reach their full potential: A reflection based on literature, case studies and our own experiences. *Food Security,* 11(1), 23-42. https://doi.org/10.1007/s12571-018-0874-4

Andersen, K. F., Forbes, G. A., Andrade-Piedra, J. L., Buddenhagen, C. E., Fulton, J., Gatto, M., Khidesheli, Z., Mdivani, R., Xing, Y., & Garrett, K.A. (2020). An integrated seed health strategy and phytosanitary risk assessment: Potato in the Republic of Georgia. In preparation.

Andrade-Piedra, J. L., Bentley, J., Almekinders, C., Jacobsen, K., Walsh, S., & Thiele, G. (eds.) (2016). *Case studies of root, tuber and banana seed systems*. CGIAR Research Program on Roots, Tubers and Bananas (RTB), Lima: RTB Working Paper No. 2016-3. ISSN 2309-6586. 244 p. http://dx.doi.org/10.4160/23096586RTBWP20163

Bentley, J. W., Andrade-Piedra, J., Demo, P., Dzomeku, D., Jacobsen, K., Kikulwe, E., Kromann, P., Kumar, P. L., McEwan, M., Mudege, N., Ogero, K. Okechukwu, R., Orrego, R., Ospina, B., Sperling, L., Walsh, S., & Thiele, G. (2018). Understanding root, tuber, and banana seed systems and coordination breakdown: A multi-stakeholder framework. *Journal of Crop Improvement* 32(5), 599-621. https://doi.org/10.1080/15427528.2018.1476998

Delaquis, E., Andersen, K. F., Minato, N., Cu, T. T. L., Karssenberg, M. E., Sok., S, Wyckhuys, K. A. G., Newby, J. C., Burra, D. D., Srean, P., Phirun, L., Le N. D., Pham, N.T., Garrett, K. A., Almekinders, C. J. M., Struik, P. C., & de Haan, S. (2018). Raising the stakes: Cassava seed networks at multiple scales in Cambodia and Vietnam. *Frontiers in Sustainable Food Systems,* 2 (73). https://www.frontiersin.org/article/10.3389/fsufs.2018.00073/full

International Potato Center (CIP). (2019). National plan for improving seed potato in Georgia. Tbilisi (Georgia). https://hdl.handle.net/10568/100492

Minato, N., Sok, S., Chen, S., Delaquis, E., Phirun, L., Le, V. X., Burra, D. D., Newby, J. C., Wyckhuys, K. A. G., & de Haan, S. (2019). Surveillance for Sri Lankan cassava mosaic virus (SLCMV) in Cambodia and Vietnam one year after its initial detection in a single plantation in 2015. *PLOS ONE.* https://doi.org/10.1371/journal.pone.0212780

Ogero, K., Pamba, N., & Walsh, S. (2015). Review and learning workshop on Marando Bora (Quality Vines) sweetpotato seed systems case study in the Lake Zone, Tanzania. Paper presented at the Victoria Palace Hotel, Mwanza, Tanzania, 27–28 January 2015.

Ogero, K. O., Kreuze, J. F., McEwan, M. A., Luambano, N. D., Bachwenkizi, H., Garrett, K. A., Andersen, K. F., Thomas-Sharma, S.& van der Vlugt, R. A. A.(2019). Efficiency of insect-proof net tunnels in reducing virus-related seed degeneration in sweet potato. *Plant Pathology,* 68, 1472–1480. https://doi.org/10.1111/ppa.13069

Ouma, T., Kavoo, A., Wainaina, C., Ogunya, B., Karanja, M., Kumar, P. L., & Shah, T. (2019). Open data kit (ODK) in crop farming: Mobile data collection for seed yam tracking in Ibadan, Nigeria. *Journal of Crop Improvement*, 33, 605–619. https://doi.org/10.1080/15427528.2019.1643812

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, 316–328.

Simbare, A., Cheikh Bassirou Sane A. B., Nduwimana, I., & Omondi, B. A. (2020). Diminishing diversity of East African Highland bananas in BBTD outbreak areas of Burundi: The effect of both disease and control approaches. *Sustainability,* 12, 7467. https://doi.org/10.3390/su12187467

Sperling, L. (2008). *When disaster strikes: A guide for assessing seed security*. Cali: The International Center for Tropical Agriculture (CIAT). https://hdl.handle.net/10568/69690

Thiele, G. (1999). Informal potato seed systems in the Andes: Why are they important and what should we do with them? *World Development,* 27, 83–99.

Thomas-Sharma, S., Abdurahman, A., Ali, S., Andrade-Piedra, J. L., Bao, S., Charkowskif, A. O., Crook, D., Kadian, M., Kromann, P., Struik, P.C., Torrance, L., Garrett, K. A., Forbes, G. A. (2015). Seed degeneration in potato: The need for an integrated seed health strategy to mitigate the problem. *Plant Pathology,* 65(1), 1-16. https://doi.org/10.1111/ppa.12439

ANNEX. BRIEF GLOSSARY

For a more complete glossary, see the *Glossary of Root, Tuber and Banana Seed Systems* (Delaquis et al. 2020), which is one of the tools of this user guide.

Banana—also includes plantains, unless otherwise indicated.

Certification (of seed)—government regulation that includes some form of inspection and control to ensure that seed is healthy and of a recognized variety.

Clean seed—seed that is healthy, free of disease. Grain seed must also be free of dirt and other inert matter.

Formal seed system—An organized chain that produces and supplies certified seed and seed of modern varieties.

Host resistance—the natural, genetically-conferred ability of a plant to defend itself from a specific pest.

Improved variety—a modern crop variety produced in a formal breeding program.

Informal seed system—a seed system that is not regulated by government, but is operated by farmers and sometimes by traders as well.

Key informant interview—qualitative interview with a list of topics and issues to be covered in a session.

Open-ended question—one allowing the broadest possible responses, such as "What kind of seed do you use?" In contrast, closed-ended questions allow a limited range of replies, e.g. "Do you plant certified seed?"

Pest— Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products.

Planting material—any seed, but usually used to refers to vegetative seed such as suckers, stems, tubers, vines, or roots used to plant a new crop.

Quality assured seed—seed that has undergone some sort of formal quality control, including certified and quality declared (QDS) seed.

Quality declared seed (QDS)—seed not from a formal system, but the quality is assured through the reputation of the producer group.

R package—A system which implements statistical techniques.

Seed—planting material for vegetatively propagated crops, including stem and root cuttings of cassava and sweet potato, and suckers of bananas, as well as 'true' seed.

Seed system—the network of stakeholders involved in providing, managing, replacing, and distributing the seed of a particular crop in a certain area.

Snowball sampling—A method for identifying interviewees by asking each person surveyed to recommend other people for the study. Especially useful when there is no list of the target group (the sampling universe) at the start of the study.

True seed—also called botanical seed. Organ produced by sexual reproduction within the fruit of a plant, capable of producing another plant.

Value chain—all the activities required to bring a product (like seed) from conception, through production, transformation and delivery to consumers.

RESEARCH PROGRAM ON Roots, Tubers and Bananas

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a partnership collaboration led by the International Potato Center implemented jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA), and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), that includes a growing number of research and development partners. RTB brings together research on its mandate crops: bananas and plantains, cassava, potato, sweetpotato, yams, and minor roots and tubers, to improve nutrition and food security and foster greater gender equity especially among some of the world's poorest and most vulnerable populations.

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