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Impact and use assessment of genetic plant material from the Bioversity's International Musa Germplasm Transit Centre (ITC) in the Latin America and Caribbean Region

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Abstract

Bananas (*Musa* spp.) are among the most consumed fruit worldwide. They are an important food source due to nutritional value and relative ease of production. In Latin America and the Caribbean alone, 20 million tons of bananas are locally consumed annually, in addition to being one of the world's most important regions for banana and plantain production and export. *Musa* users need genetic material for their research. The purpose of this study was to obtain a clearer view of the various ways *Musa* is used, and how *in vitro* collections and genebanks like the Bioversity's International *Musa* Germplasm Transit Centre (ITC) are essential to different areas of work, including but not limited to scientific research. We surveyed *Musa* users in the MUSALAC region about accessions they have received from the ITC in the past 15 years and how they have been utilized in each country. We also identified country examples of important impacts of accessions originating at the ITC. The institutions selected for case studies are: the Corporación Bananera Nacional (CORBANA) in Costa Rica, the Instituto de Investigaciones de Viandas Tropicales (INIVIT) in Cuba, and the United States Department of Agriculture Tropical Agriculture Research Station (USDA-TARS) in Puerto Rico. All three represent countries where people consume *Musa* on a daily basis in multiple ways. All three are research institutes that work for the conservation and improvement of varieties of local importance and each case study reported how the material from the ITC has affected the communities where they work in various ways. This study demonstrates the value of having a safe place for *Musa* diversity in a fast-developing world that is increasingly reliant on monoculture practices. The more the needs of the germplasm users are understood, the better the services the ITC can provide, and the clearer communication can become. The accessibility to genebanks such as the ITC, where safe and clean plant material can be acquired, directly affects researchers, farmers, producers, educators, students and consumers of *Musa*.

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1 Introduction

Bananas (*Musa* spp.) are among the most consumed fruit worldwide. They are an important food source due to nutritional value and relative ease of production (Liu 2009). In many rural areas of banana consuming countries, they can provide up to a quarter of people's daily calorie intake (FAO 2018). In 2004, Naylor et al. included bananas and plantains on a list of what they described as "orphan crops"—commonly used in some regions, but not a focus of scientific research, funded by either private or public institutions. However, over the years, global use of bananas has grown while more scientific attention has been devoted to enhancing knowledge about this crop. In Latin America and the Caribbean alone, 20 million tons of banana are locally consumed annually, in addition to being one of the world's most important regions for banana and plantain production and export (Dita 2013). Enhancing the use and value of this crop depends on improving the availability of information and planting material for scientists, educators, farmers, producers, and consumers. One of the resources that aims to enhance and facilitate the use value of bananas is MusaNet [1].

MusaNet is the global *Musa* genetic resources network of banana researchers working together within five thematic areas (Conservation, Diversity, Evaluation, Genomics and Information) to meet the targets set out in the Global Strategy for the Conservation and Use of *Musa* Genetic Resources (MusaNet 2016). The global network also links the four regional banana networks (MUSALAC for Latin America and the Caribbean, Innovate Plantain for Western and Central Africa, BARNESA for Eastern and Southern Africa and BAPNET for Asia and the Pacific) and the ProMusa information platform.

Musa users within the four regional networks need genetic material for their research. Obtaining clean, safe and healthy plant genetic material of new varieties from around the world was, in the past, a difficult task. The purpose of Bioversity's International Musa Germplasm Transit Centre (ITC) is to provide such material. The ITC, established in 1985 under the auspices of FAO, is managed by Bioversity International and hosted at the Katholieke Universiteit in Leuven, Belgium. The ITC has the world's largest *in vitro* collection of *Musa* germplasm in the world. Over 1,500 accessions are kept in medium-term storage in vitro and over 900 accessions are preserved in long-term storage by cryopreservation. Every year, hundreds of *Musa* accessions are shipped from the ITC around the world, clean of pests and diseases, to many different types of institutions including research centers, germplasm collections, and universities

[1] For more information see www.musanet.org.

(MusaNet, 2016). Users can request material from the ITC via the Musa Online Ordering System at https://www.crop-diversity.org/mgis/moos/how-to-order.

Most of the economic value of genetic resources is derived from use, and the greatest share of that value concerns what is/can be generated today rather than in the future. The purpose of this study was to obtain a clearer view of the various ways *Musa* is used, and how *in vitro* collections and genebanks like the ITC are essential to different areas of work, including but not limited to scientific research. We surveyed *Musa* users in the MUSALAC region about accessions they have received from the ITC in the past 15 years and how they have been utilised in each country. Countries in this region are some of the main producers and consumers of banana, and many research and educational institutes dedicate time and effort to learning more about the genus *Musa*, protecting its diversity and learning about new varieties around the world. Following this study, the *Musa* Usage Survey will be used to evaluate use of accessions in the three other regional networks, which include Asia and the Pacific, Eastern and Southern Africa and Western and Central Africa.

This study builds on previous work undertaken by Bioversity International. In 2010, Garming, Van den Houwe & Roux completed an in-depth study that included a conceptual approach for assessing the benefits and costs of the ITC, analysis of distributions since its inception in 1985, and a user survey, with emphasis on costs of conservation and distribution. The authors found a continuous increase in the number of accessions requested and distributed to over 100 countries from the ITC since its foundation in 1985. For a number of countries, the ITC is the only source of clean and healthy *Musa* germplasm. Survey respondents reported the "role of ITC as most important source of new *Musa* germplasm for research as well as for the distribution of improved germplasm to farmers". They described the ITC as a unique genebank resource for them because of the diversity and free services provided. In addition, many pointed out that the ITC added value to their research. According to 38% of respondents, the ITC was the only source of viable germplasm—without which their work may not have been feasible. Many countries have strict plant importation policies and the ITC provided an easy and effective way to transfer safe and healthy germplasm to those who needed it. In countries with strict quarantine, survey respondents reported that they could not have conducted their research at all without the ITC since it was the only legal source of germplasm.

Following the 2010 study, the Global *Musa* Survey was conducted in 2012-2013. This survey was sent to key *Musa* collections around the world to gather information to facilitate the update of the MusaNet Global Strategy for the Conservation and Utilization of *Musa* Genetic Resources and to increase support

for crucial collaborative actions. By October of 2015, 56 collections had responded to the Global Survey (MusaNet 2016).

The 2010 study and the Global *Musa* Strategy provided the baseline and conceptual background for the *Musa* Usage Survey. The Usage survey addresses the impact that the ITC has had in Latin America and the Caribbean over the past 15 years. The *Musa* Usage Survey will also be sent to members of the other Regional Networks.

The *Musa* Usage Survey and the subsequent Impact Study, both presented here, go further than the previous surveys in justifying the value that the ITC has in the world of *Musa* research and production. Through the *Musa* Usage Survey we show how organizations use the plant genetic material once it is received from the ITC, and why they maintain certain accessions to distribute or include in their own collections. The *Musa* Usage Survey results lead us to an Impact Study based on three cases that describe in depth how accessions are used and who benefits from them at different levels of usage. The Impact study included field visits and interviews to key informants.

This report presents the assessment approach and methods used for creating and conducting the *Musa* Usage Survey. Results of the survey are presented in sections corresponding to the subdivisions of the survey. The second part of the results presents the Case Studies carried out. Following the results, we discuss the Impact Stories developed along with their representative pathway diagrams. Finally, conclusions on the survey and pathways are discussed.

2 Assessment approach and methods

This study was carried out in two parts. The first step was a survey of all requestors of material from 2000-2015 in the Latin America and Caribbean region (LAC). The second step focused on identifying key examples of important impacts of accessions originating at the ITC. Each organization received a copy of the *Musa* Usage Survey, which requested information related to accessions originating from the ITC, requested by that user, and about local varieties and their current uses.

Before we began the survey, we collected and compiled lists of all individuals and organizations that had requested plant material from the ITC during the period 2000-2015. The lists included the name of the contact who made the request, the name of the organization or institute represented, the amount of accessions requested, and the purpose of the request that was identified at the time it was made. After reviewing responses, we grouped these as shown in Table 1.

After preparing the census list of all users, we contacted each MusaNet Regional Network and country representative with the current information we had. Where possible, the representatives provided updated contact information for each user. All users were surveyed.

Individual users with expired or no contact information were eliminated from the initial list. A total of 57 individuals were surveyed. We received 18 completed surveys, representing 32%. A response rate of this magnitude was expected for a mail survey of this type, following the outcome of the ITC 2010 Garming Survey (218 surveys were sent and 63 responded, or 27%). Similarly, a large-scale survey undertaken among requestors of germplasm from the US National Germplasm System in 2002 had a response rate of only 36% (Smale & Day-Rubenstein 2002).

The *Musa* Usage Survey was a structured questionnaire divided into four main sections (Musa Usage Survey). The first included general information about the user, such as contact and collection information as presented in *Musa* Contacts (www.musacontacts.org) and on MusaNet (www.musanet.org). It also included information about the requested material from the ITC, number of accessions, year requested and the purpose for each request. If a user requested material from the ITC multiple times, all the data was included in a table in this section. The second section of the survey was designed to follow-up on material received from the ITC by each user. It asked if any of the accessions were included into their current collections, and why these accessions were or were not maintained. The idea was to understand what traits might have been important in deciding to include a new accession into a collection, and to see if current use of those accessions had changed from the original request purpose. In this section the survey also asked about any research data or publications that included use of an accession originating from the ITC. Other questions in this section intended to identify any further impact an accession from the ITC may have had in the local market, or if any had contributed to the food security of that region. The third section of the survey asked users to identify ten of the top *Musa* varieties used in their country, specifying the variety, its main use and the most important traits that variety had for the country. The last section in the *Musa* Usage Survey was a set of open answer questions about specific needs that the users may have to maintain their collections, what difficulties exist in the region regarding *Musa,* and to try and identify if there are any needs with which Bioversity could help. Answers to this section were consolidated and categorized for easier representation.

A copy of the Musa Usage Survey in English and Spanish was sent to a representative of each of the organizations or institutes that requested the material, along with a description of what the survey was and

what purpose it served. We obtained consent from all Musa users in the MUSALAC Regional Network that completed the survey, as shown in Table 2.

In the second part of the study, we identified survey responses that represented important examples of the potential impact of accessions originating at the ITC. Answers from the completed surveys were tabulated and carefully analysed to identify Impact Story Case Studies. Users with potential case studies were contacted via email and Skype with follow-up questions in order to develop an impact story. Three final impact stories were developed.

For each case study, a potential impact pathway was designed based on the survey answers and follow-up communications with each representative. These potential impact pathways were then evaluated by the user institution's representative. Based on the pathway design, key informants who would be important in understanding the true impact of ITC accessions in each country were selected by the representative. Key informants were interviewed and visited at field and production sites to gain better understanding of the dynamics of each institution and how the role of each *Musa* user fit into the pathway. The number of key informants varied by case. After identifying key informants, a series of interview questions were designed for each case study.

The institutions selected were visited by the principal investigator (author), and key informants were interviewed individually. The visits consisted of travelling to field and production sites and visiting each institute's collection. Key informants included students, professors, researchers, farmers, producers and consumers, among others. After reviewing each case study, the impact pathways were re-evaluated to represent the impact of accessions originating at the ITC, beneficiaries and stakeholders.

3 Survey results

The results are presented in order corresponding to the sections of the survey.

3.1 Section I. General information

We received 18 completed surveys: 3 from individuals in Ecuador, 2 from Brazil, 2 from Colombia, 2 from Cuba, and 1 from Bolivia, Costa Rica, Guadeloupe, Haiti, Honduras, Mexico, Peru, Puerto Rico and Venezuela. Of these, 14 responded that they keep a current *Musa* collection. Each individual was asked to identify the role of their collection as National, Regional, Global, Unknown or Other specified. Table 3 shows terms as defined in the survey. Half of the collections described themselves as National, 5 did not answer, 2 were unidentified, 1 was described as Global, and 1 was described as part of a breeding

program (Figure 1). Users were also asked to describe how accessions are kept in their collections. Half of the collections are kept as Field Collections, 4 in Tissue Culture, 3 did not respond to this question, 1 uses Cryopreservation, and 1 answered they do not back-up their collections (Figure 2).

3.2 Section II. Follow-up information: ITC material

Musa users in this section were asked to provide information about accessions originating from the ITC. Eight of the users said they maintained some of the accessions received from the ITC, 2 do not maintain any accessions, and 8 did not respond to this question. Of those who maintain accessions in their collections, 7 keep them in their field collections, and 2 in a greenhouse environment, the rest did not respond to this question. No user identified Tissue Culture or Cryopreservation as a form of preservation for accessions they received from the ITC.

Another important point was to have the user identify the purpose for which these accessions were maintained as part of their current collections. The top reasons for maintaining accessions were: Breeding/Evaluation for Breeding, Multiplication and further dissemination, and Characterization. Figure 3 shows all responses to this question and Figure 4 compares the Main Purpose for Requesting Accessions from the ITC vs. the Main Purpose for Maintaining these Accessions as part of their current collections. When asked to identify the most important traits of the accessions maintained, eight users responded. Important traits included: productivity, genetic diversity and resistance to pathogens and drought.

Three users stated that some accessions had not been maintained in their current collections because they lacked useful traits to be added or they did not survive the acclimation period. Only one user (Fundación PROINPA in Bolivia) stated they had distributed accessions in 2004 to farmers in the Tropic of Cochabamba to renew planting material lost in the 1990s, 9 users reported not having distributed any accession, and 8 users did not respond to this question.

Other examples described by users as important impact of the accessions from the ITC in their countries are outlined in Table 4.

3.3 Section III. Musa usage

Users were asked to list the top ten varieties of *Musa* used in their country and identify the main local uses and traits of these varieties. Eighteen users responded with a total of 98 top varieties mentioned (Annex A). Options for uses included: food (includes any description of edible product made at home or eaten fresh), research (includes any topic of research described by the user), export (includes export to

other countries), commercial (includes sale at large scale farms and markets), and processing (includes any product that requires processing such as chips, flour, etc.). Sixty-five percent of the varieties were used mainly for food, followed by 15% commercial use, 14% research, 3% for export and 3% used for processing (Figure 5). Major traits of the top ten varieties identified included 41% productivity, 23% good taste, 11% resistance to disease, 9% nutritional value, 6% resistance to pathogens. Other important traits represented less than 5% of the top varieties (Figure 6).

3.4 Section IV. Follow-up for collections

In the last section of the survey users were asked to identify any specific difficulties they had in the management of their collections, along with how they thought Bioversity International could be of help to them. The main concern was limited financial and human resources. Figure 7 shows distribution of main concerns.

4 Case study results

After surveys were received, possible case studies were selected that would help describe in greater detail the impact of accessions originating from the ITC in different countries of the MUSALAC Region. Five users were selected first, based on answers corresponding to impact and usage questions. These included: BioRecolté from Haiti, PROINPA from Bolivia, INIVIT from Cuba, CORBANA from Costa Rica and USDA-TARS from Puerto Rico. Communication via email and Skype was established with each of these users to start a dialogue about the potential impact of ITC accessions. Three out of the five users were selected based on responses to follow questions about potential impact stories, availability to participate in future conversations and interviews, accessibility for visits and interviews, and current work underway with accessions from the ITC.

The two users that were not selected were BioRecolté from Haiti, and Promoción e Investigación de Productos Andinos (PROINPA) from Bolivia. The researcher from Haiti described use of accessions for developing micropropagation protocols and trials at their laboratory facilities. Some of the accessions were acclimatized to be distributed and used by small farmers and NGOs for planting in deforested areas, and production of fruit for fresh consumption or as banana wine and vinegar. The dried leaves were used as a nutrient source for the production of mushrooms.

The group from Bolivia used accessions from the ITC for multiplication and research in their breeding program. Two of the accessions, Williams and Valery, were distributed to local farmers. They were introduced in the local market in Bolivia during the 1980s and lost over time to natural causes. The ITC

accessions were used to re-introduce the varieties in the early 2000s and eventually 50,000 plants were distributed by PROINPA to the farmers. They also reported preference for the quality and taste of the ITC accessions.

The institutions selected as Case Studies for the development of impact stories were: the Corporación Bananera Nacional (CORBANA) in Costa Rica, the Instituto de Investigaciones de Viandas Tropicales (INIVIT) in Cuba, and the United States Department of Agriculture Tropical Agriculture Research Station (USDA-TARS) in Puerto Rico. All three represent countries where people consume *Musa* on a daily basis in multiple ways. All three are research institutes that work for the conservation and improvement of varieties of local importance. Each reported how the material from the ITC has affected the communities where they work in various ways. The stories developed from the Case Studies will be discussed next.

5 Impact stories

As noted in the methods, impact stories were developed from the case studies. For each case, the participating institutions were visited to carry out interviews and site visits. Key informants were selected by the site's director or representative and were interviewed. All key informants signed a consent form for audio and video recording and a consent form for utilization of photographs of the sites and of them.

After each visit we designed what we call "impact pathways". These flow charts describe the use of accessions originating from the ITC by different beneficiaries. At least one key informant at each level of the pathway was interviewed.

The following sections describe each case study and impact pathway.

Costa Rica: CORBANA **(Corporación Bananera Nacional)**

CORBANA is a public research center focused on the study of edible bananas, and the development of new technologies to improve their production. CORBANA originally requested material from the ITC during the years 2001, 2002, 2010 and 2011 as part of a variety of research projects in collaboration with Bioversity International. These include the International Musa Testing Programme (IMTP) and the Taxonomic Reference Collection (TRC). Their research and evaluation using these accessions is not yet finished but many varieties from the ITC have been incorporated into their field collection.

CORBANA works directly with students and farmers. Students of all ages visit the collection to learn about diversity and the phylogenetic history of *Musa*. University students also have the opportunity to

work in the laboratories at CORBANA as interns or graduate students. It is important to CORBANA that the community is aware and involved in the work they do, because farmers, large producers and consumers are their reason for existing. Farmers frequent the facilities at CORBANA for workshops and other educational opportunities, but mostly for the services CORBANA provides them. The scientists at CORBANA focus their work on finding ways to improve *Musa* production and maintenance for farmers. For example they research important pathogens and provide farmers and producers with new materials to manage pests, or varieties that are more resistant to pathogens and stresses. Other services are chemical evaluations of soil and plants to help in the management of fertilizers for farmers' crops. CORBANA actively serves as a classroom where people learn about diversity and the value of having a germplasm collection. Consumers are the last step of the pathway and the final beneficiary from CORBANA's work; therefore, consumer feedback is increasingly important to them for establishing research priorities (see Figure 9).

The scientists at CORBANA value the services of the ITC for the work they do. When asked to describe the relationship CORBANA has with the ITC, Informant #1 Costa Rica (scientist from CORBANA) said the following:

> "I consider this place (ITC) as a very important one, first from the point of view as a mover of germplasm, and as a conserver of germplasm. In terms of germplasm movement, it is very important to guarantee that germplasm movement is done following all safety measures. Introducing germplasm into country X, but following all protocols and all international guides, such as the ITC does is essential. They also conserve the most variability possible and there are still so many cultivars to be found. There is still a lot of work to be done, and the need for a place like the ITC is important."

In terms of *Musa* diversity consumed and grown commercially, scientists from CORBANA agree that there is a lot of work to do to educate communities about the potential that other varieties can have. The favourite Costa Rican varieties are Gran enano (Cavendish), Curare (horn plantain), Datil (Pisang Mas-Sucrier) and Criollo (Gros Michel), for their taste and traditional preparations. Although these may be the Costa Rican preferences, scientists at CORBANA believe there is still a need to diversify preferences.

> "Where are we moving towards? There is much work to be done. We hope to change the perceptions of the people, which is the most difficult thing." Informant #2 Costa Rica (scientist from CORBANA)

Cuba: INIVIT **(Instituto de Investigaciones de Viandas Tropicales)**

INIVIT is a national agriculture research center that focuses on the research of roots, tubers and bananas (Instituto de Investigaciones de Viandas , 2017) . Scientists at INIVIT carry out valuable research for their country's food production systems. INIVIT requested material from the ITC in the years 2001 and 2004. They have received accessions from the ITC for their participation in IMTP and for their genetic improvement programmes. During the IMTP trials, they selected some varieties with useful traits to incorporate into their breeding programmes. Specifically, two accessions from the ITC, Zanzibar and Pisang Ceylan, were parent plants to two INIVIT hybrids that were subsequently widely distributed in Cuba and highly requested for their fast growth, taste and production levels.

Accessions from the ITC have impacted a broad spectrum of people and communities in Cuba due to the structure of INIVIT and its research programmes (see Figure 10). INIVIT studies and produces improved varieties of roots, tubers, and bananas, and distributes them according to climate, soil conditions, and consumer needs and preferences to each province.

> "The use of genetic diversity is for us, fundamental." Informant #1 Cuba (scientist from INIVIT)

Each province then reproduces the selected plants via tissue culture and distributes them in large quantities to each farmer or large-scale producer of that region. Along the way, many students and researchers benefit from the work being done at INIVIT and from the diverse collections they maintain. The impact INIVIT has on the population is very cyclic as their research strongly depends on the needs of the consumers and the environment in which the producers will be growing their crops. As for preferred varieties from consumers, there is Cavendish, Manzano INIVIT (dwarf Silk), and Burro CEMSA (Bluggoe).

When asked about the role of the ITC on the work done at INIVIT Informant #2 (scientist from INIVIT), explained the following:

> "We have a lot of problems to solve now. What do we need to do? Take all measures and be prepared. And this is where you (Bioversity International/the ITC) can help us. You help us reintroduce varieties that are not sick."

> "We need places like the ITC to help with the transit of our varieties. To help us get our plants to other collections to do research. We want to be prepared in advance for problems such as Fusarium before it arrives here."

> "Today's problems can be solved through the application of science and technology and by the integration of knowledge into what we do. We need to work together and help each other as scientists."

Puerto Rico: USDA-TARS

TARS is the United States Department of Agriculture, Agricultural Research Service-Tropical Agriculture Research Station. It is their mission to research, preserve, introduce, evaluate and distribute tropical and subtropical crops (Tropical Crops and Germplasm Research, 2017). TARS collaborates with the Puerto Rican Department of Agriculture and with the University of Puerto Rico's Experimental Stations for agricultural education. TARS has received plant material from the ITC as part of IMTP, TRC and Field Verification experiments during the years 2006, 2008, 2010, 2013 and 2014. Without the ITC, the research done on *Musa* would become much more difficult to accomplish.

> "If the ITC didn't exist, those 1,500 accessions hadn't been collected at some point, and preserved long term, the *ex situ* germplasm collections wouldn't have had the chance to evaluate those materials, that are always virus indexed. They (the ITC) are always making sure that they are sending very healthy, disease-free plants. The ITC has been very responsive when we've been interested in something particular. They send it relatively quickly." Informant #1 Puerto Rico (scientist from USDA-TARS)

> "Definitely, if it could be carried out at all it would be very difficult to source the plants. To be able to assemble all those plants from one source, one location, would've been very difficult." Informant #1 Puerto Rico (scientist from USDA-TARS)

To date, none of the original material has been distributed to farmers or producers, but many people have been engaged with the collection and with the work done by researchers at the station with the accessions that have come from the ITC. Students, interns, extension agents for the University and Department of Agriculture, all benefit from the research done at TARS.

> "They have a great value, such as scientific value, educational value and even cultural value. They have been part of our local research projects. It is our mission, as a research agency, to evaluate accessions in replicated trials and find out if they possess agronomic traits of importance. We also work with undergraduate and graduate students and they get to experience diversity through these projects." Informant #2 (laboratory technician USDA-TARS)

Many accessions from the ITC have been included into the TARS field collection, which is frequently visited by growers and Extension Agents. TARS recently published two *Musa* collection catalogues that serve the scientific community as research and educational tools (Irish et al. 2016). When an experimental accession has potential beneficial traits, such as size or resistance to a pathogen, it is further evaluated in replicated trials. For example, Obubit N Tanga, received from the ITC, is currently being evaluated because of its high production rate and quality of fruit. The most commonly consumed bananas in Puerto Rico are the Cavendish type bananas and the Maricongo plantain; however, other varieties are also produced on a smaller scale and sold directly from the farmers.

6 Conclusions

This study demonstrates the value of having a safe place for *Musa* diversity in a fast-developing world that is increasingly reliant on monoculture practices. The more the needs of the germplasm users are understood, the better the services the ITC can provide, and the clearer communication can become. This study is a beginning at understanding the relationships between *Musa* users (be it researcher, or end consumer) and genebanks that provide the plant material.

Although the survey response rate was low (32%), it was to be expected. Many of the individuals that were on the original list of ITC plant recipients are no longer available and many of the original contact details were expired. In some cases, we were able to update this information, in others the contacts were lost. Even though the response rate was low, we expect that upcoming similar outreach in other Regional Networks to have a higher rate of participation. Since the survey started in 2015, curators and other relevant *Musa* users have been personally informed about the *Musa* Usage Survey and our work during their participation in recent MusaNet regional workshops.

The main goal of the survey was to learn about the current use of accessions originating from the ITC in the different countries where accessions have been sent. Results show that although half of the respondents state that they maintain accessions in their collections, the other half remained unresponsive.

It is important to try and understand why questions about current use, distribution and impact of accessions from the ITC in other locations, were not answered. Some of the key informants from the case studies believe there may be hesitation to share information because of the conditions of the Standard Material Transfer Agreement (SMTA) associated with the requested material. There is confusion among users about what the SMTA means and how it applies to the kind of work they do. Some accessions might be distributed for local consumption or small research projects, but users will not report this in the survey, due to fear that they are working against the SMTA. However, those who did say they maintain accessions identified the main use as research.

The second goal of the survey was to learn about diversity in local varieties and their main uses and traits. What we found was that even with access to a large variety of plants, the diversity of top varieties of *Musa* used in each country is low. Cultural uses and tradition are very powerful sources of impact that can limit the varieties a community is interested in using. In the MUSALAC Regional Network, the main varieties are used for food and selected because of their productivity and taste, over varieties with stronger resistance to pathogens.

After evaluating the case studies and designing the three "Impact Pathways" it was clear to see the extended role the ITC has in the use of *Musa* by a variety of beneficiaries. The accessibility to genebanks such as the ITC, where safe and clean plant material can be acquired, directly affects researchers, farmers, producers, educators, students and consumers of *Musa*.

Another important observation is a need for diversification in local markets. There are new threats to plant health such as the fungus *Fusarium oxysporum* species cubense tropical race 4 that his causing a lot of damage in Asia and in some countries in Africa but not in Latin America for which very strict measures are being taken to avoid any possibility for the fungus to enter this region. *Musa* genebanks and local collections are working to also find alternatives to local preferences. The data from this survey will be part of a larger group when other Regional Networks are surveyed. Research must continue to grow and further communication among the Regional Networks will strengthen the process. The surveys and field visits conducted for this study have helped reinforce communication between Bioversity International and the ITC users, and identify specific difficulties users have, such as managing resources and use of plant material with SMTAs.

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Table 1. Purpose for material request from the ITC, as identified by users.

User identified Purpose	**Description of Purpose**
Breeding/Evaluation for breeding	Used in breeding programs specifically, or to evaluate traits preferred for breeding
Multiplication and further dissemination	Included accessions for non-research purposes, *e.g.* maintaining a collection
Evaluation of agronomic or other traits	Evaluating plant traits for farmers and producers
Characterization (morphological, molecular, etc.)	Characterization of accessions, either for use in collection or as part of a project
Fundamental research	Used in research on plant traits
Applied research	Used in research with applications for use by farmers/producers
Conservation *in vitro*	Used in *in vitro* collection
Conservation in field	Used in field collection
Cryopreservation	Used in cryopreserved collection
Other (please specify)	Requested for more than one purpose or a specific project (like the International *Musa* Testing Programme (IMTP) or Field Verification)

Table 2. Organisations or institutes surveyed per country.

Country	Organization
Barbados	CARDI- Caribbean Agriculture Research and Development Institute
Brazil	EMBRAPA- Empresa Brasileira de Pesquisa Agropecuaria/Brazilian Agricultural Research Corporation
Bolivia	PROINPA- Promoción e Investigación de Productos Andinos
	UAGRM- Universidad Autónoma Gabriel René Moreno
	Unknown
Colombia	AUGURA- Asociación de Bananeros de Colombia
	CIAT- Centro Internacional de Agricultura Tropical/International Center for Tropical Agriculture
	CIB- Corporación para Investigaciones Biológicas
	CORPOICA- Corporación Colombiana de Investigación Agropecuaria
	FEDEPLATANO- Federación Nacional de Plataneros de Colombia
	UNIBAN- Union of Colombian Banana Growers
	Universidad Nacional de Colombia, Bogotá
Costa Rica	CATIE- Centro Agronómico Tropical de Investigación y Enseñanza
	Chiquita Banana
	CORBANA- Corporación Bananera Nacional
	Corporación de Desarrollo Agrícola Del Monte
	Dole
Cuba	IBP- Instituto de Biotecnología de las Plantas
	INCA- Instituto Nacional de Ciencias Agrícolas
	INIFAT- Instituto de Investigaciones Fundamentales en Agricultura Tropical
	INIVIT- Instituto de Investigaciones de Viandas Tropicales
Dominica	DAAS- Dominica Academy of Arts and Sciences
Dominican Republic	Biochemicals Consultant
	CEDAF- Centro para Desarrollo Agropecuario y Forestal, Inc.
	CIAZA- Centro de Investigaciones Aplicadas a Zonas Áridas
	IDIAF- Instituto Dominicano de Investigaciones Agropecuarias y Forestales
	ISA- Instituto Superior de Agricultura
	LNB- Laboratorio Nacional de Biotecnología la Duquesa
	MIP- Musa Instituto Politécnico Loyola
Ecuador	ESPOL- Escuela Superior Politécnica del Litoral / CIBE
	FUNDAGRO- Fundación para el Desarrollo Agropecuario
	INIAP- Amazonía- Instituto Nacional de Investigaciones Agropecuarias
	INIAP- Pichilingue- Instituto Nacional de Investigaciones Agropecuarias
Guadeloupe	CIRAD Guadeloupe- Centre de Coopération Internationale en Recherche Agronomique pour le Développement
Guatemala	Unknown

Haiti	BioRecolte
	Petionville
Honduras	FHIA- Fundación Hondureña de Investigaciones Agrícola
	Galil Agrobiotech
Jamaica	BB- Banana Board
	MOA Jamaica- Ministry of Agriculture
	SRC- Scientific Research Council
	TRS- Tropical Agriculture Systems
Martinique	CIRAD Martinique- Centre de Coopération Internationale en Recherche Agronomique pour le Développement
	IRD- Línstitut de Recherche pour le Développement
Mexico	CICY- Centro de Investigación Científica de Yucatán
	INECOL- Instituto de Ecología
	INIFAP- Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias
Nicaragua	VVOB-UNA- Universidad Autónoma de Nicaragua
Peru	INIA Peru- Instituto Nacional de Innovación Agraria Agraria
	SENASA- Ministerio de Agricultura- Servicio Nacional de Sanidad
	Unknown
	UNPRG- Universidad Nacional Pedro Ruiz Gallo
Puerto Rico	Jardines CC
	USDA, ARS TARS- United States Department of Agriculture, Agricultural Research Service, Tropical Agriculture Research Station
Trinidad and Tobago	IICA- Inter-American Institute for Cooperation on Agriculture
	MOA TT- Ministry of Agriculture
Venezuela	INIA- Instituto Nacional de Investigaciones Agrícolas. Centro Nacional de Investigaciones Agropecuarias (CENIAP)
	UCV- Universidad Central de Venezuela
	UNET- Universidad Nacional de Táchira en San Cristóbal
	Unknown

Table 3. Terms to identify role of *Musa* collection.

Type of role	**Definition**
National	mainly for local or national conservation, distribution and use
Regional	for conservation, and distribution at the regional level, e.g. Americas, Asia, Africa, etc.
Global	mainly for international conservation, distribution and use
Other: specify	e.g. only for the use of a specific institute's breeding program

Table 4. Impact of accessions from the ITC described by users.

Musa User	Impact of ITC accessions
Fundación PROINPA, Bolivia	Material from ITC was preferred by farmers for their taste, more than the varieties that are resistant to Sigatoka.
CORBANA, Costa Rica	Material from the ITC enhanced the variability of the germplasm bank, this is positive for educational purposes since the collection is visited by many students of different ages.
INIVIT, Cuba	Accessions from the ITC have been characterized for their productivity, and tolerance to pathogens and incorporated to the national breeding program.
ESPOL, Ecuador	Cryopreservation protocols were developed with some of the ITC accessions.
USDA-TARS, Puerto Rico	The Taxonomic Reference Collection[2] is a teaching tool at the field site and a taxonomic reference in molecular and genetic work. One accession, Obubit N Tanga, has an average of 65 fruit per bunch (15 better than the industry standard). It is being observed for productivity research.

Table 5. *Musa* production area in the three countries selected. The data was obtained from the Crop Mapper online resource- Banana Mapper (Crop-Mapper, 2017).

Country	*Musa* cultivar primarily produced	Cultivated area (ha)	Amount produced (t)	Year data collected	Original data source
1. Costa Rica	Cavendish	43,024	1,825,498	2015	CORBANA Costa Rica Dr. Jorge Sandoval
2. Cuba	multiple varieties included in calculation	97,040	678,917	2013	MUSALAC country representative Dr. Luis Pérez Vicente
3. Puerto Rico	Plantain AAB	2,834	110,872	2013	MUSALAC country representative Dr. Mildred Cortés

[2] "The Taxonomic Reference Collection (TRC) is a set of accessions representing the main subgroups of cultivated bananas and the two wild species that are the origin of most domesticated bananas, *Musa acuminata* and *Musa balbisiana*." For more information visit Taxonomic Reference Collection

8 Figures

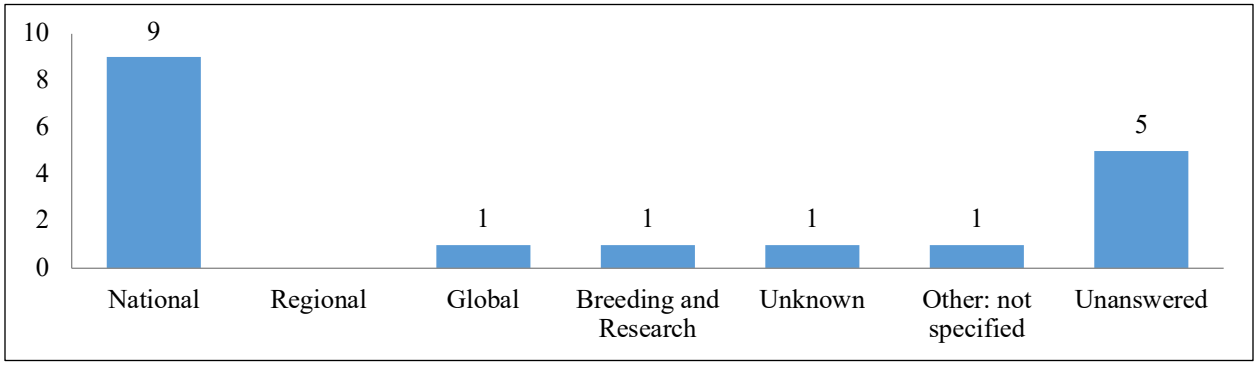

Figure 1. Role of collection as defined by user.

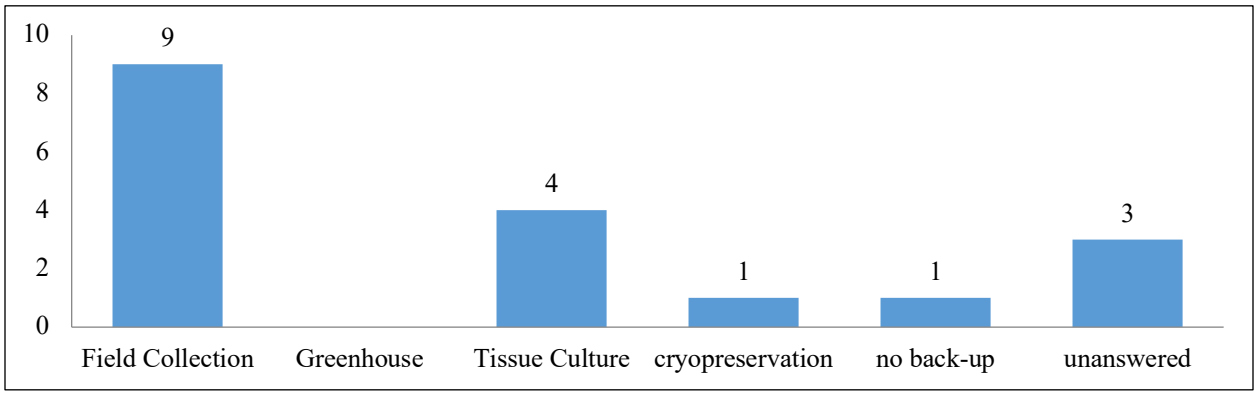

Figure 2. How accessions are kept in collections.

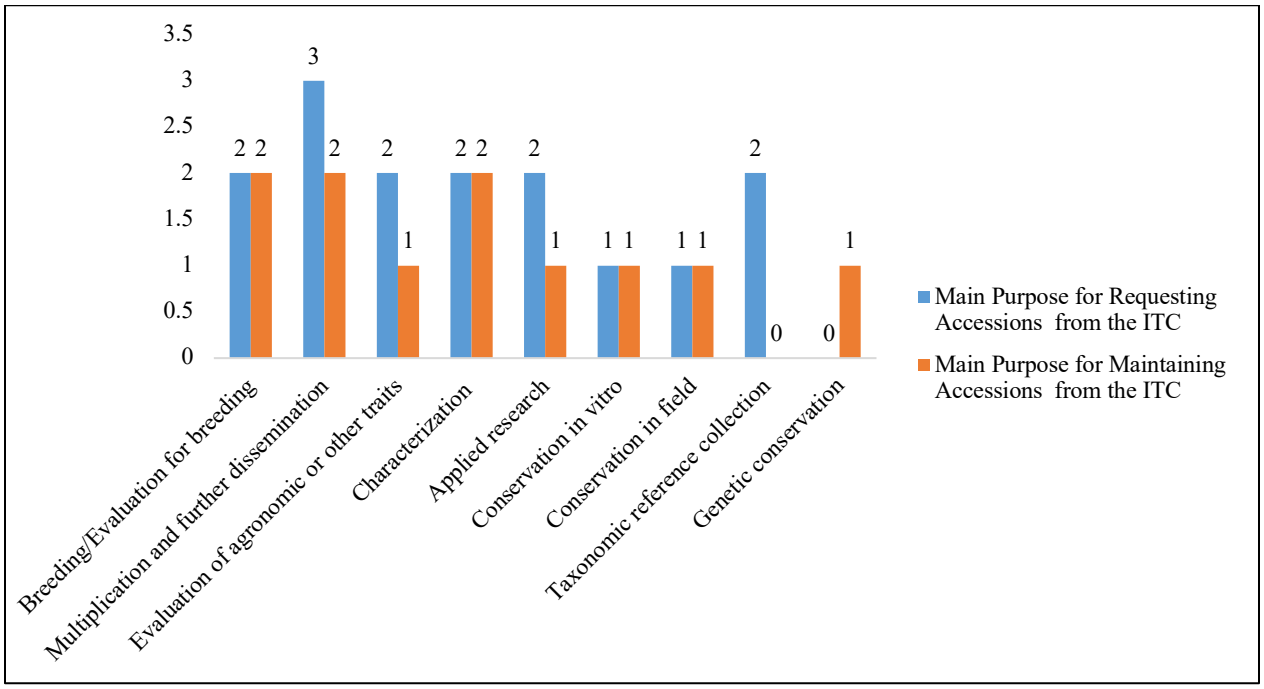

Figure 3. Purpose for maintaining accessions from the ITC in user current collections.

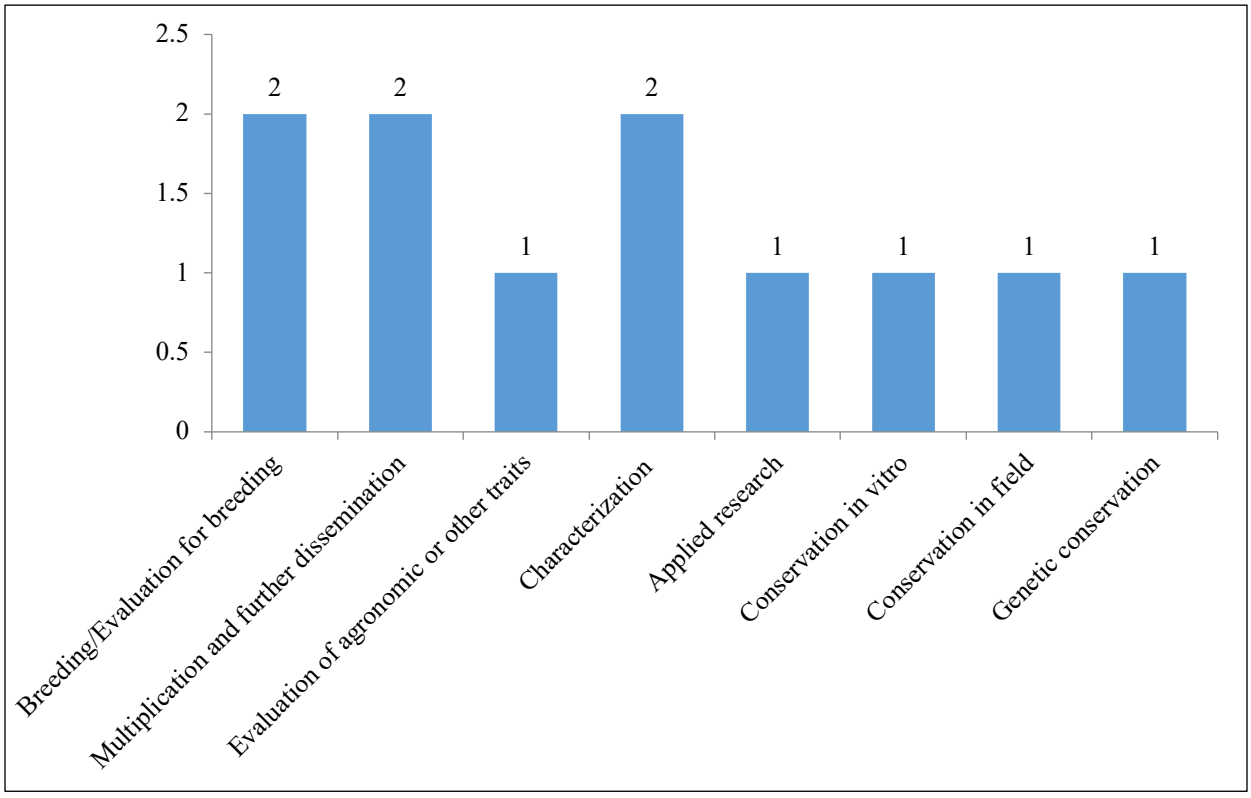

Figure 4. Purpose for requesting material vs. Purpose for maintaining accessions in collection.

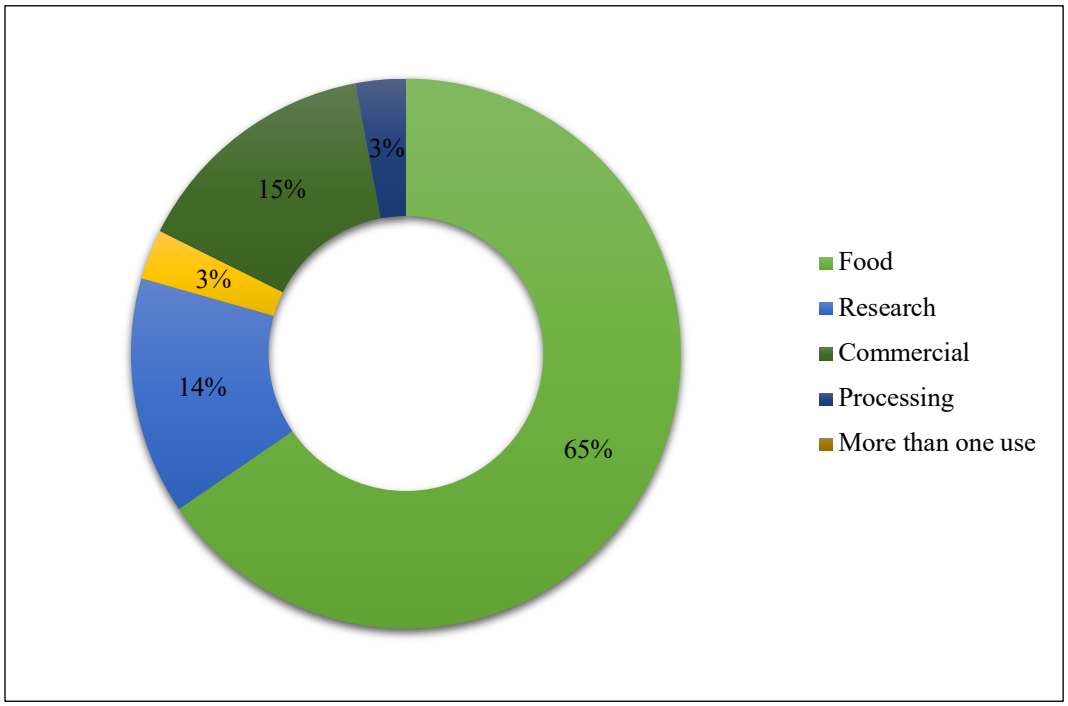

Figure 5. Uses of top varieties.

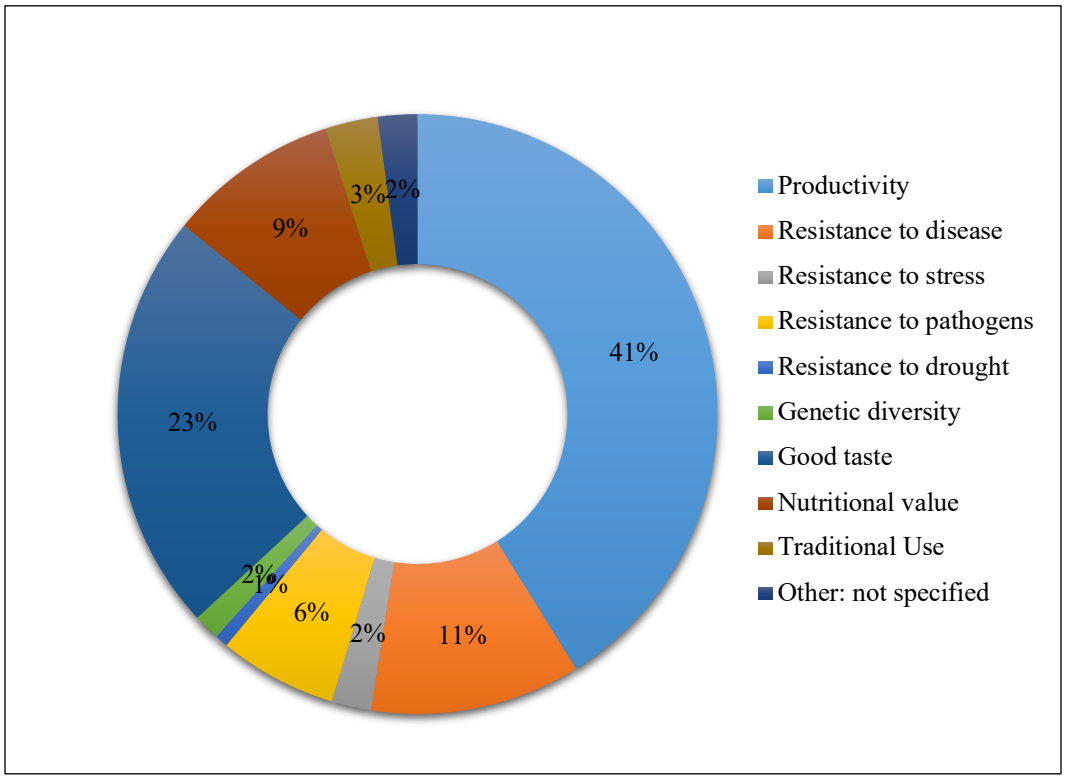

Figure 6. Major traits of top varieties.

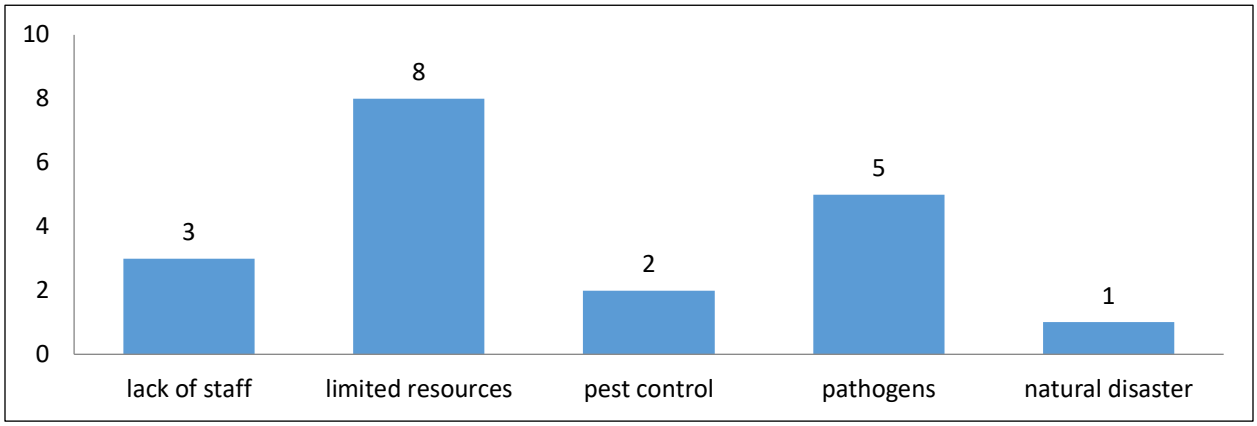

Figure 7. Users identified specific difficulties in maintaining their collections.

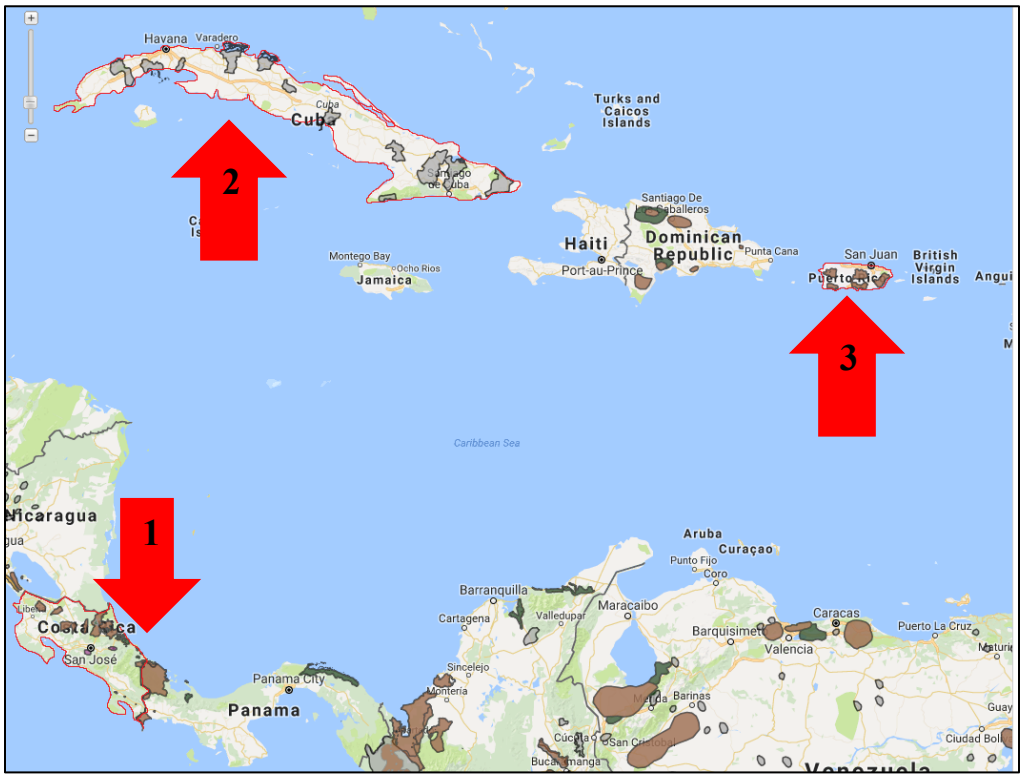

Figure 8. Highlighted areas are identified on the Banana Mapper as production areas.

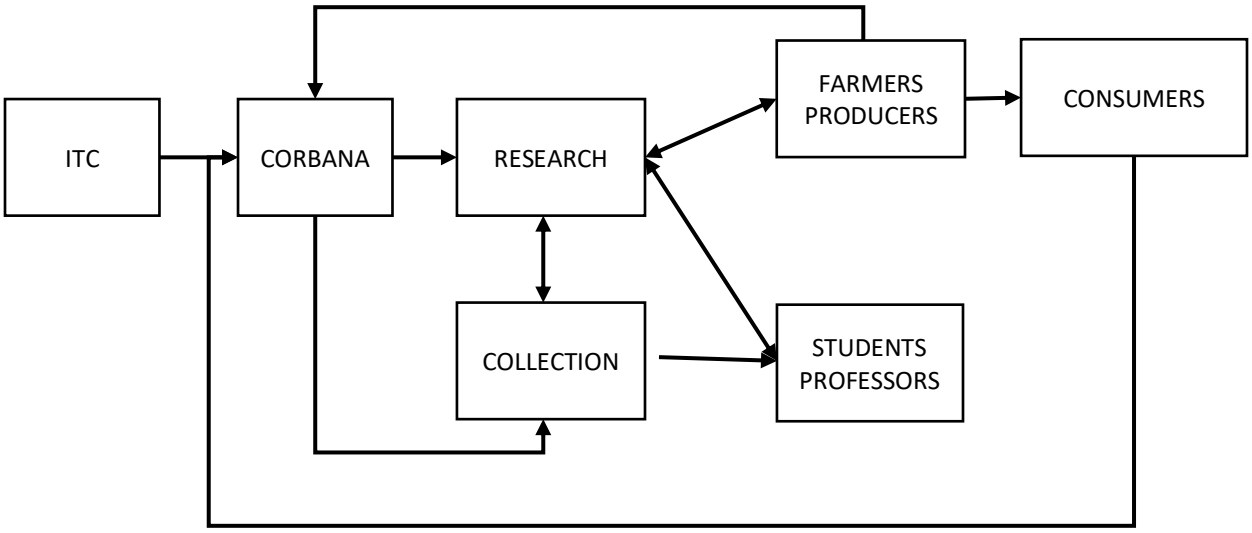

Figure 9. Impact Pathway of ITC Accessions in Costa Rica through CORBANA.

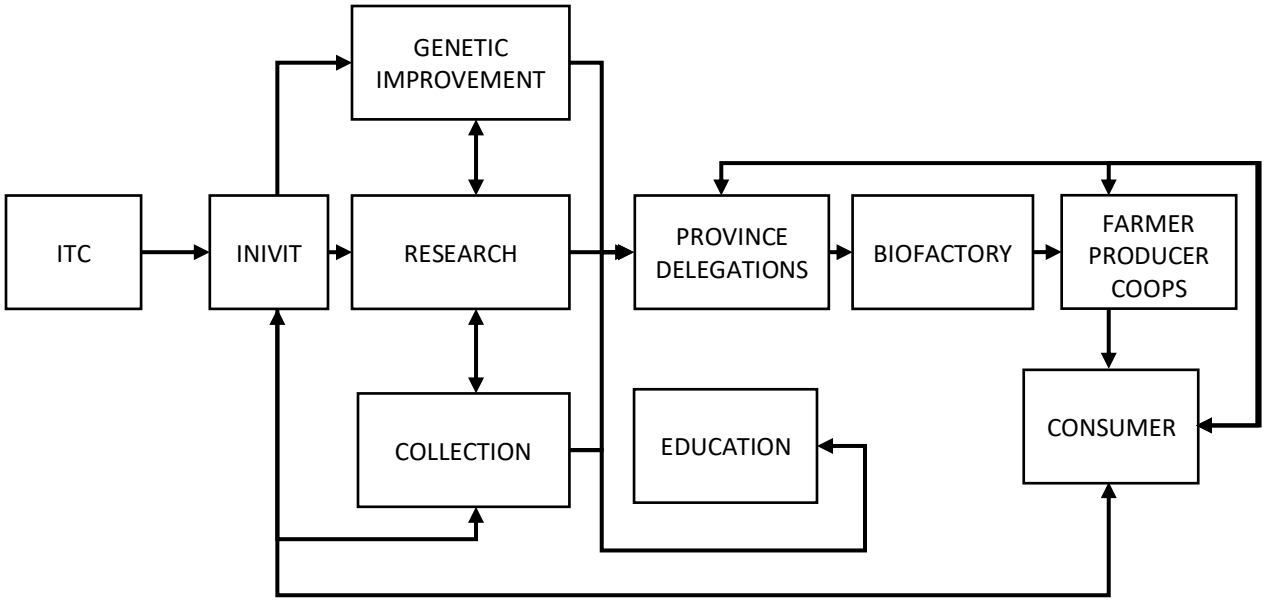

Figure 10. Impact Pathway of ITC Accessions in Cuba through INIVIT.

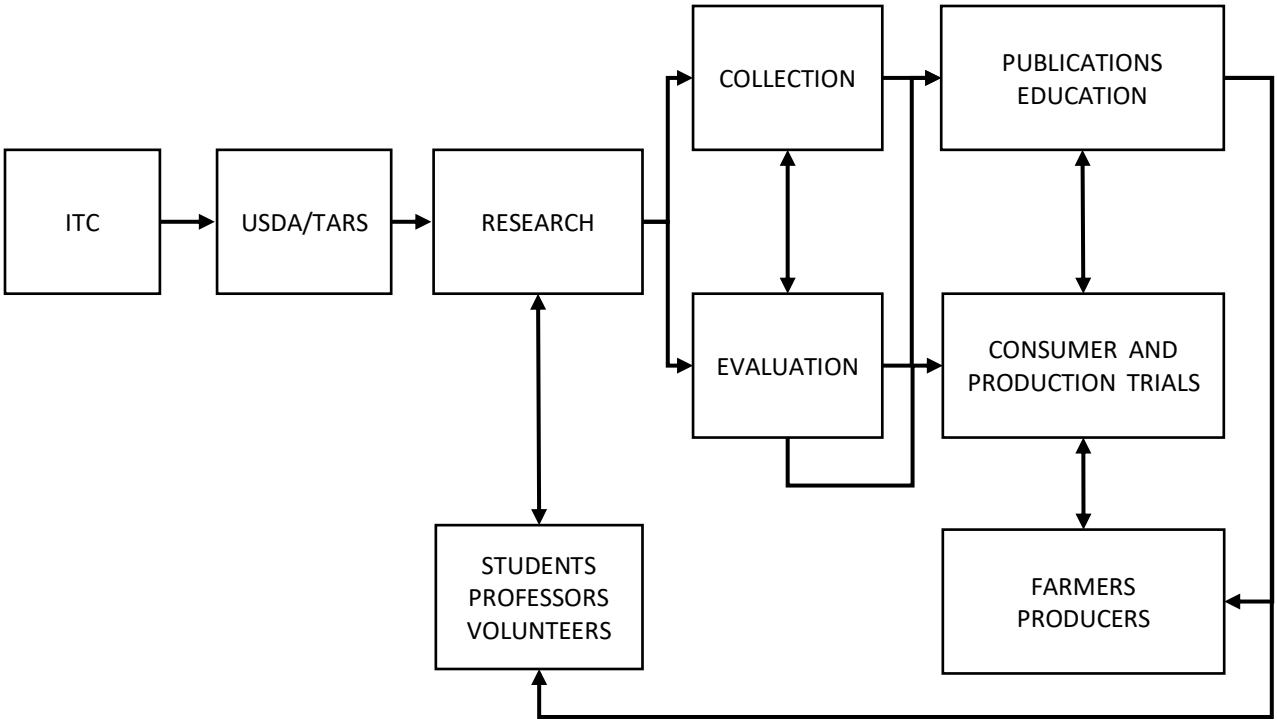

Figure 11. Impact Pathway of ITC Accessions in Puerto Rico through USDA-TARS.

9 Annexes

Annex A. Top varieties identified in MUSALAC Region. Varieties were reduced to 70 from 98, after eliminating synonyms. Some synonyms may still be present. Local names used.

Variety	Group	Subgroup	Frequency of named as a top variety	Variety	Group	Subgroup	Frequency of named as a top variety
Dominico	AAB	Plantain	5	Galil-13 (GN)	AAA	Cavendish	1
Gros Michel	AAA		5	Guineo morado	AAA	Red	1
Williams	AAA	Cavendish	5	Harton	AAB	Horn Plantain	1
Grande Naine	AAA	Cavendish	5	INIVIT PB-2012	AAA		1
Dominico Harton	AAB	Plantain	3	INIVIT PV-0630	AAB		1
FHIA-21	AAAB		3	INIVIT PV-2011	AAB		1
Manzano	AAB	Silk	3	Kingala			1
Valery	AAA	Cavendish, giant cavendish	3	L9			1
Barraganete			2	Limeño			1
Maçã (Pisang Mas)	AA	Sucrier	2	Mafafo (Bluggoe)	ABB	Bluggoe	1
Orito			2	Mambeethu			1
Prata Anã			2	Manzano INIVIT	AAB	Silk	1
Balbisiana	BB	Balbisiana	1	Maqueño			1
Banane blanche	AAB	Plantain	1	Maricongo	AAB	Plantain	1
Banane corne	AAB		1	Morado (Red Daka)	AAA	Red	1
Bluggoe	ABB	Bluggoe	1	Namwa Khom			1
BRS Princesa			1	Narincão			1
Burro CEMSA	ABB	Bluggoe	1	Ngoen			1
Calcutta	AA		1	Niño (sucrier)	AA	Sucrier	1
CEMSA 3/4	ABB	Bluggoe	1	Norteño			1
Cooking bananas	AAB	Plantain	1	Ouro			1
Costeño			1	Pacovan			1
Curare	AAB	Plantain	1	Pelipita	ABB		1
Curare enano (Dwarf plantain)	AAB	Plantain	1	Pisang Berlin			1

Datil	AA	Sucrier	1	Pisang lilin	AA		1
Dominico gigante	AAB	Plantain	1	platano cachaco	AAB		1
Enano	AAA	Cavendish	1	Platano macho	AAB	Plantain	1
Enano guantanamero	AAA		1	platano pompo			1
F galil-10 (GN)	AAA	Cavendish	1	Poteau (equivalent of Poteau Geant)			1
FHIA-18	AAAB		1	Prata Catarina			1
FHIA-25	AAA		1	Saba	ABB	Saba	1
Figo			1	Seda Gigante			1
Figue Pomme	AAB	Dessert	1	Terra			1
Freysinette (equivalent of Figue sucrée)	AA	Sucrier	1	Terra Maranhão			1
Galil-12 (GN)	AAA	Cavendish	1	Tuugia	AA		1

Image 1. Dr. J. Miguel González Zuñiga explaining the effects of Sigatoka on the collection at CORBANA.

Image 2. *Musa* Collection at CORBANA. The plants are organised by group and subgroup to be used as an educational tool.

Image 3. Diversity of varieties at a fruit and vegetable shop in Costa Rica.

Image 4. Personnel from Bioversity International, INIVIT and the Ministry of Agriculture (MINAG) in the Cienfuegos Province. From left to right: Jesús Negrín (Director of Seed Production MINAG), José A. Vargas Santiago, Jorge López Torres (Research Scientist INIVIT), Sirena Montalvo Katz (Consultant Scientist Bioversity International), José de la C. Ventura Marín (Director of Phytotechnology INIVIT), Lianet González Díaz (Director of Genetic Improvement INIVIT) and Roberto Rodriguez (sub delegate of Province Cienfuegos MINAG).

Image 5. Manzano INIVIT plant growing in collection at INIVIT.

Image 6. Burro CEMSA fruit in a street vendor cart.

Image 7. Dr. Brian Irish and Yaleidis Méndez preparing a PCR reaction in the laboratory.

Image 8. Field Verification site at TARS.