SUMMARY OF THE GLOBAL STRATEGY FOR THE CONSERVATION AND USE OF *MUSA* GENETIC RESOURCES

A consultative document prepared by the Global *Musa* Genetic Resources Network (MusaNet)

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MusaNet

Bioversity International

CGIAR Research Program on Roots, Tubers and Bananas

CGIAR Research Program for Managing and Sustaining Crop Collections

MusaNet is the Global Network for *Musa* Genetic Resources, with representatives from various banana research institutes, organizations and networks that support *Musa* research. MusaNet aims to optimize the conservation and use of *Musa* genetic resources by coordinating and strengthening such conservation and related research efforts of a worldwide network of public and private sector stakeholders.

www.musanet.org

MusaNet is coordinated by Bioversity International which is part of the CGIAR Systems Organization - a global research partnership dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources.

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Bioversity International delivers scientific evidence, management practices and policy options to use and safeguard agricultural and tree biodiversity to attain sustainable global food and nutrition security.

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ABSTRACT

Dessert and cooking bananas (*Musa* spp.) are crops of great importance for both the subsistence and the livelihoods of people in developing countries. Banana is also one of the most popular fruits worldwide. From their origin in Southeast Asia and Melanesia, bananas have spread to and diversified in the Pacific, Asia, Africa, Latin America and the Caribbean.

The nature of banana as a vegetatively-propagated, mostly polyploid and relatively sterile crop poses unique constraints for its conservation, breeding and improvement. Scientists have recently sequenced the two original parent genomes (*Musa acuminata* and *Musa balbisiana*) of most edible banana, which has led to a deeper understanding of *Musa* genetic diversity and its origins. New molecular techniques such as genotyping by sequencing (GBS), RADseq and next generation sequencing (NGS) are helping unlock the genetic potential of banana. By linking these tools to phenotypic data, the genetic improvement of banana can ultimately help minimize losses due to pests and diseases and other stresses such as drought. Selection and breeding efforts are also directed toward improving global productivity and nutrition.

Implicit in the use of *Musa* diversity is the need to safeguard that diversity for future generations. National and regional *ex situ* collections, found in tropical regions across the globe, are working towards conserving and documenting their local banana diversity. These collections also play an important part in understanding the known diversity, through networks, partnerships and collaboration on activities such as the Taxonomic Reference Collection (TRC) exercise (see page 14).

Increasing focus is also being placed on exploring *in situ* diversity growing on farms and in the wild. The Bioversity International Transit Centre's (ITC) global collection in Belgium aims to conserve all *Musa* species and cultivars by *in vitro* storage or cryopreservation, and is now also investing in conserving seeds of wild *Musa* species. The ITC has a mandate to distribute viable, virus-free material that has confirmed genetic integrity and is well documented for the benefit of all users.

INTRODUCTION

The vision of the Global Strategy is a world in which *Musa* genetic diversity is secured, valued and used to support livelihoods of hundreds of millions of farmers through sustainable production and improved food and nutrition security.

To achieve these goals, it includes actions that aim to:

i. assess *Musa* genetic diversity and correctly identify and fill gaps in the diversity conserved,

ii. conserve the entire *Musa* gene pool in perpetuity in *ex situ* collections, *in situ* in the wild and on farms, and enable access to this material,

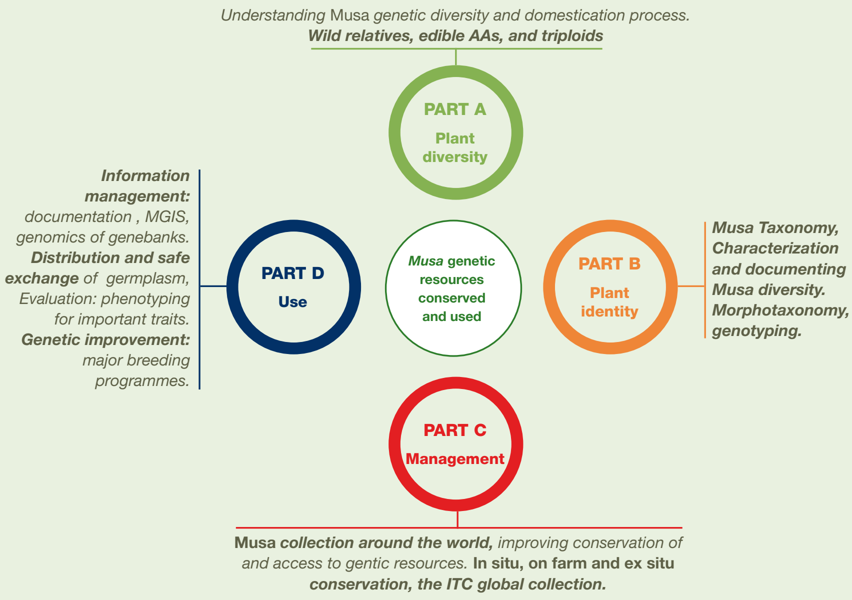
iii. maximize the use of genetic diversity through comprehensive characterization and identification of the accessions and their evaluation,

iv. apply genomics tools to banana to better support breeding and

v. document the germplasm and make the information easily accessible to users.

The Global Strategy is intended to be used as a roadmap for the *Musa* genetic resources community as it proposes a collaborative framework for activities on the conservation and use of *Musa* genetic resources. It covers numerous topics dealing with *Musa* genetic resources, with the 12 chapters divided into four main parts: *Diversity*, *Identity*, *Management* and *Use* (see figure 1). It concludes with a section summarizing actions to be taken, and then a series of annexes of important complementary information.

Figure 1. *Diagram visualising the components of the Global Strategy.*



This summary booklet generally follows the structure of the full Global Strategy document, which is published on the MusaNet website (see www.musanet.org). The content of the summary booklet is divided into two parts: *Where We Are Today* and *Actions for Tomorrow*. Key *Actions for Tomorrow* are highlighted in bold type.

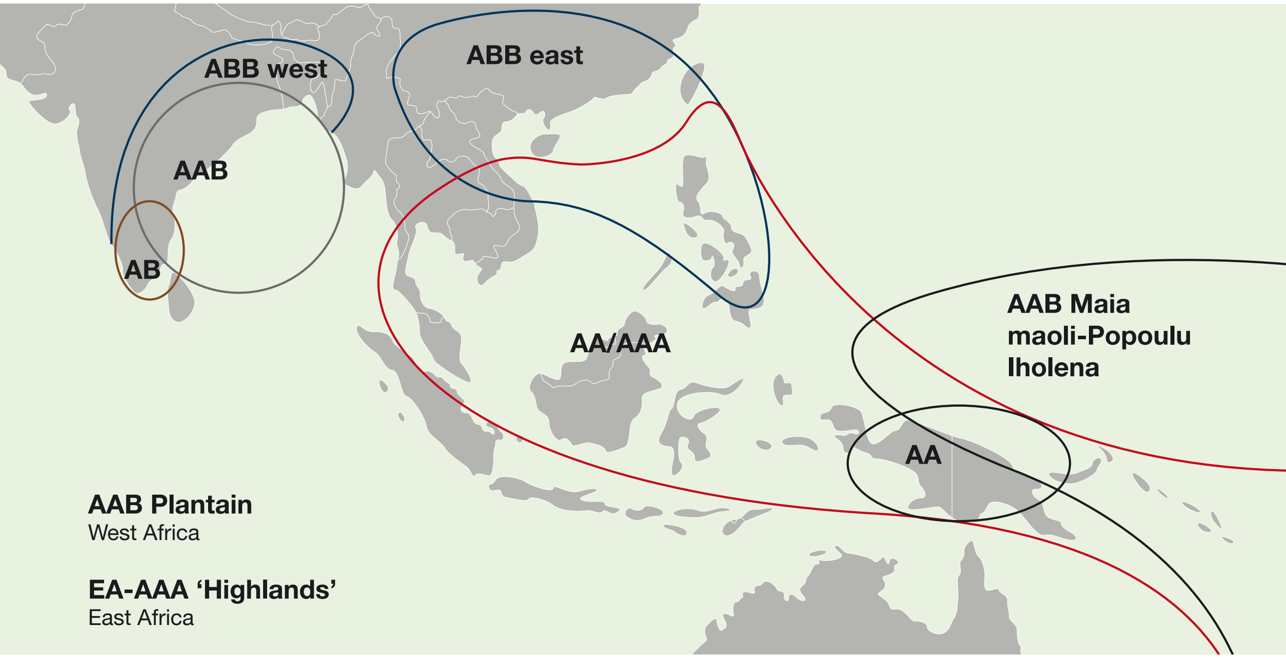
WHERE WE ARE TODAY

MUSA DIVERSITY

All edible bananas belong to the genus *Musa*, which represents a group of possibly 70 forest-dwelling species, distributed between India and the Pacific, as far north as Nepal and extending to the northern tip of Australia.

Wild species are diploid. Varieties of the species *Musa acuminata* have been domesticated to eventually produce a non-seeded fruit with sufficient pulp. During this slow process some descendants crossed with *Musa balbisiana*, and the resulting cultivars commonly contain one or more A or B genomes, or both, classified in

Figure 2. *Geographical distribution of where the edible AA and the main triploid banana cultivar groups/subgroups dominate. (Source: De Langhe et al. 2009).*



genomic groups as diploids (AA and AB), as triploids (AAA, AAB, ABB), and as some rare tetraploids (AAAA, AAAB) (see figure 2).

Edible AA diploids offer a wide spectrum of genotypes from which the breeding programmes can select the most appropriate parents. Some of them still produce more or less fertile pollen and/or when artificially pollinated, can produce hybrids with seedless fruits.

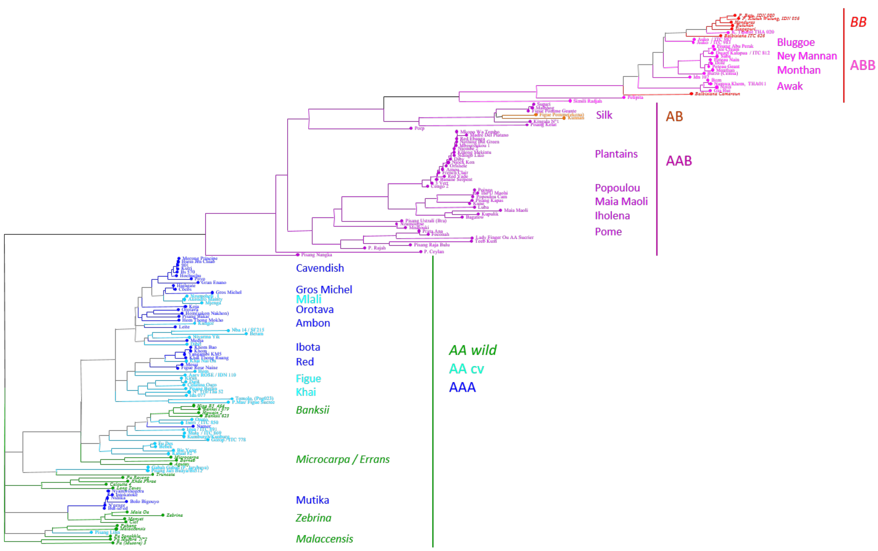
Triploids are cultivated throughout the (sub) tropical world. The combination of genomes held by cultivars, once identified, is used as the first level of classification of banana, the "group". Each ''group" consists of a number of ''subgroups" with different plant appearances and different genotypes. The success of triploids, such as the AAA subgroup Cavendish, is due to their high vigour and fruit growth rate. For AAB or ABB, the *M. balbisiana* genome is believed to have added characters like tolerance to abiotic or even biotic stresses.

Globally, there is a need to collect more material to fully represent banana diversity in *ex situ* collections.

IDENTIFICATION AND CLASSIFICATION

Musa taxonomy has been a subject of research since the 19th century. The most important wild ancestor of edible bananas, *Musa acuminata*, has been extensively studied. It displays an exceptional intra-specific variability, which is more complex than is understood from its current subspecies classification, and can provide a wide range of promising material for breeding. There is an unclear taxonomy for the *M. balbisiana* intra-specific variation, and with the addition of other species, the overall classification of the *Musa* genus is a challenge. Equally, the classification of cultivated subgroups is sometimes challenging.

Figure 3. *Neighbour-Joining tree of 93 accessions with 836 DArT markers (Source: Risterucci et al. 2009).*



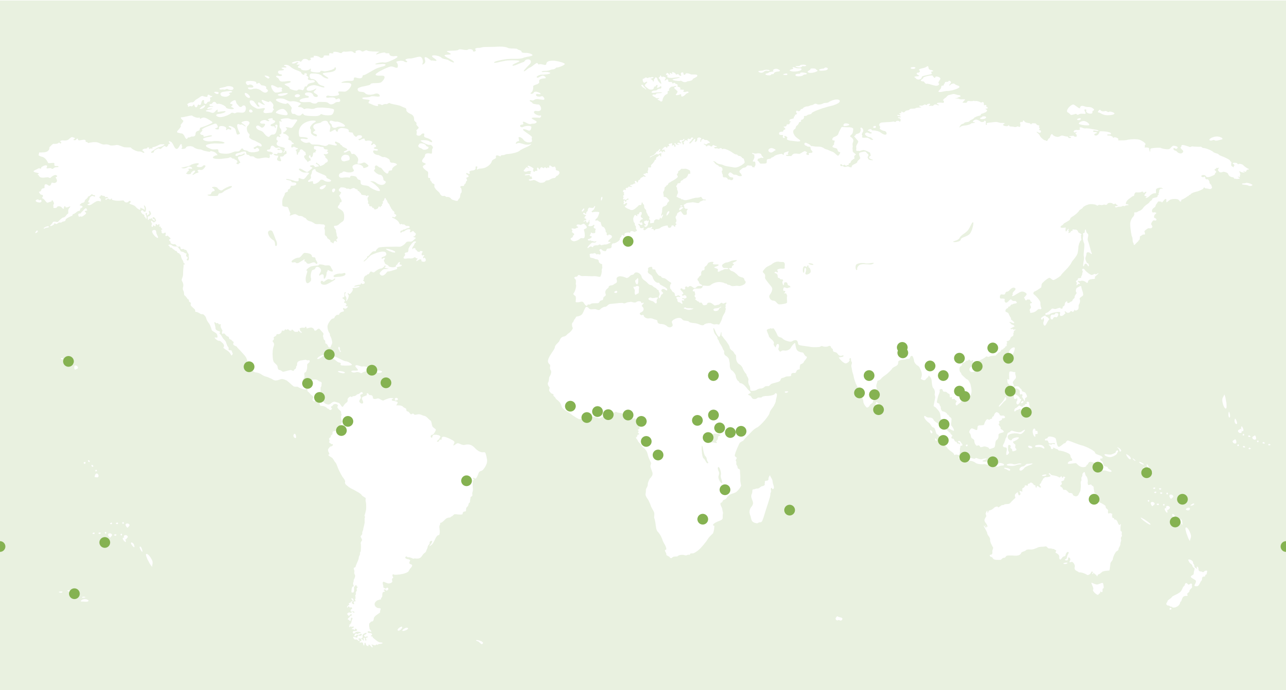


Figure 4. *Musa ex situ collections around the world.*

Characterization is the basic tool for the correct identification and classification of any cultivar. Morphological characterization is the precise qualitative description of the plant when growing in optimal conditions whereby its characteristics are maximally expressed. Molecular characterization aims to find those DNA sequences that reveal differences between cultivars and allow for the clustering of similar accessions (see figure 3). The molecular marker techniques currently used for *Musa* description are the SSR, the DArT, and the SNP, which are explained in the glossary of the full Global Strategy.

Because up to 1,000 cultivars are grown in many places over the world, some cultivars have many different local names. The lack of a standardized cultivar nomenclature is hampering banana research. Unfortunately, the morphological taxonomy of all these cultivars has not been achieved, which prevents systematic comparative investigation of morphological and molecular data. However, both morphological and molecular characterization methodologies are progressively moving towards a single harmonious system adapted to the special nature of edible banana diversity.

MUSA COLLECTIONS AROUND THE WORLD

MusaNet carried out a Global Survey of *Ex Situ* Collections in 2012-2015 to better understand the status of *Musa* diversity managed and the associated needs and priorities. According to the survey, there are currently 56 institutes conserving 9,051 accessions of *Musa* germplasm in field, 4,507 accessions in *in vitro* collections, 898 accessions in greenhouses and 926 accessions in cryopreservation collections (see figure 4 for the collection locations).

Most of the collections have been established over the past 30 years with the earliest such collection being INERA in Congo DRC, in 1933. Because the banana is a herb, its conservation in *ex situ* collections requires great care, and insufficient support has led to serious difficulties in many collections. Currently, many institutes and organizations provide key services to the global system of *Musa* conservation and use, such as molecular characterization, pre-indexing, virus indexing, quarantine services, taxonomic research and breeding programmes, but due to lack of financial support, the effective maintenance of *ex situ* collections remains problematic in many cases.

The majority of the *Musa* germplasm is maintained *in vivo*, i.e. in the many field collections around the world in the centres of origin, in the main production areas and secondary diversity regions. The field collections are important for taxonomic characterization, evaluation, training and breeding purposes. The institutes maintaining field collections are therefore an essential part of a global system for the conservation and use of *Musa* diversity as they form the network of key partnerships.

Most of the collections have been established with the mandate of conservation of the genetic resources, and support to research and breeding programmes. Most of the collections contain cultivars (introduced and from local farmers) but conservation of the wild taxa is limited and incomplete. *Musa* germplasm is managed under a range of field conditions and standards, and most have an urgent need for support. Field collections are highly vulnerable to pests, diseases, natural and other disasters, or changes in land-use and need regular replanting (regeneration).

There are few *in vitro* collections (apart from the ITC) and very few cryopreservation collections, which is a focus area for building capacity in the national and regional collections. Research is also

Photo 1. *The MusaNet characterization and documentation workshop held at NRCB, India, in 2014. Credit M. Wong/SDR*

underway on seed conservation of wild *Musa* species.

Although there is an urgent need to reduce unwanted duplication related to the identification of materials, very few collections are safely backed-up in another location or collection outside of the country. This brings risks of losing unique material not represented in the ITC. In addition, there are still gaps in the conservation of the entire genepool, particularly of the wild species that are threatened.

THE INTERNATIONAL TRANSIT CENTRE

The International *Musa* Germplasm Transit Centre (ITC), based at the Katholieke Universiteit Leuven (KULeuven), Belgium, was set up in 1985. The collection is held 'in trust' under the auspices of FAO and managed by Bioversity International. The ITC is the largest collection of *Musa* germplasm with around 1,500 accessions.

The ITC exchanges clean germplasm and provides safety back-ups for other collections. It is closely linked with many national collection partners and collaborates on research and capacity building in conservation methods.

Since 1985, the ITC has distributed more than 17,000 accessions to users in 103 countries. Key users of the ITC are the banana research community and networks that need access to biologically well-defined material as a tool for generating new knowledge, for research on resistance/tolerance to banana pests and diseases, and for evaluation and further dissemination to farmer communities for increased productivity.

Photo 2. *The in vitro medium term storage collection at the ITC. Credit N. Capozio/Bioversity International*

The ITC collection is documented in two complementary databases: the *Musa* Gene Bank Management System (MGBMS), facilitating the day-to-day management of the collection, and the *Musa* Germplasm Information System (MGIS), which makes accession-level information including passport and characterization data publicly accessible to end-users. MGIS also facilitates requesting germplasm from the ITC, through an online germplasm ordering tool.

Although the ITC is the largest *ex situ* collection of *Musa* germplasm, some cultivated groups and subgroups from key geographical areas as well as wild species are still under- or unrepresented in the collection.

IN SITU AND ON-FARM CONSERVATION

In situ conservation concerns the ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings where they have developed their distinctive characteristics (CBD, 1992). On-farm conservation has been defined as "*the continuous cultivation and management of a diverse set of crop populations by farmers in the agro-ecosystems*" where the crop has evolved. In situ maintains the evolutionary processes that allow continuous selection of new materials/genes for farmers. These materials are of increased interest for crop improvement and climate change adaptation.

Photo 3. *Bananas growing in gardens in Rwanda. Credit concretedreams.be*

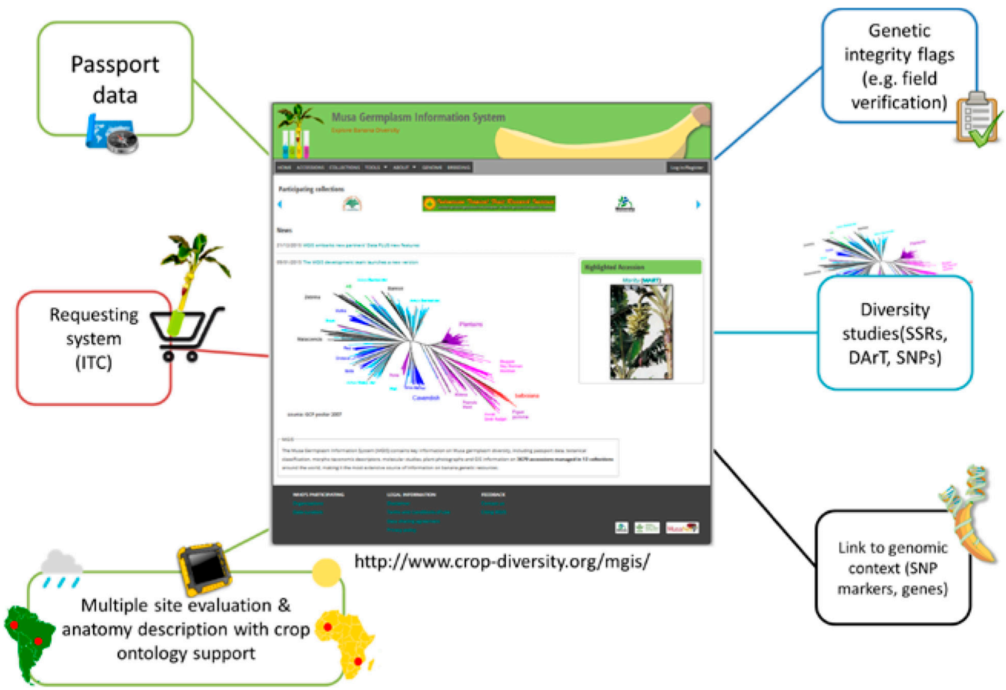
The great advantage of *in situ* and on-farm conservation is that the evolutionary processes of the wild species and traditional cultivars are maintained in a dynamic way. Unfortunately, *in situ* and on-farm genetic resources have been less studied than *ex situ* resources, as they are often influenced by complex social, political and biological factors. In addition, there is a threat to the continuity of habitat for *Musa* growing in the wild.

INFORMATION MANAGEMENT

The MusaNet Global *Musa* Survey carried out in 2012-2015 reviewed the status of documentation of genetic resources held in *ex situ* collections. Although in-house tools were identified that fulfill the needs of many collections, several genebanks still lack the effective technology to document and manage collection information.

The *Musa* Germplasm Information System (MGIS) serves to support documentation of banana genetic resource information through a Data Sharing Agreement (DSA). This information, mostly related to accession-level passport data, is described using standards and is regularly updated. In parallel, molecular data and phenotyping data for genebank accessions are being massively produced and stored independently; however interoperability with MGIS will be assured.

Figure 5. *Features and functionalities of MGIS released in January 2015.*



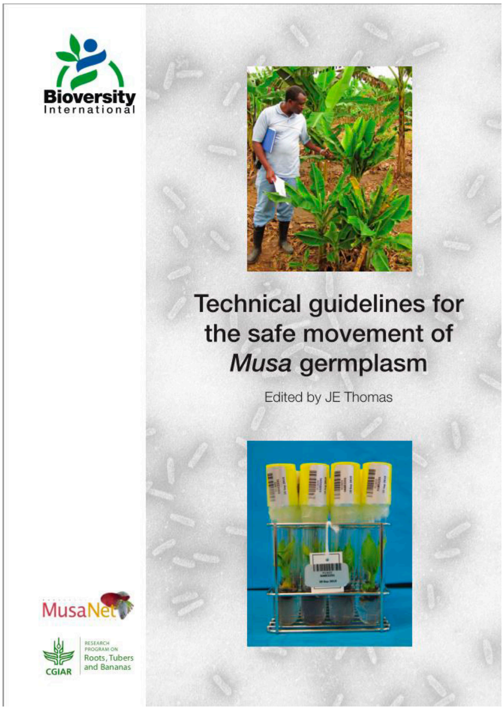
DISTRIBUTION AND SAFE EXCHANGE

A wide range of *Musa* diversity is held in the many collections that support national research programmes, of which safety duplications and exchange is often assured by the ITC. The major reliable source of *Musa* germplasm available for distribution internationally is the ITC, which holds the most comprehensive set of banana diversity that can be obtained from a single source and for which the health status is guaranteed. A few national repository and dissemination centres are also in place, but they are not able to meet the global demand for germplasm. At the moment, procedures are not uniform across all regional centres and although there are acceptable alternative protocols, they must be approved and validated before being implemented.

An important constraint to germplasm use is the difficulty faced by many scientists in obtaining materials from other countries. Furthermore, every country is dependent on genetic resources from other countries for their own needs. To address the fair sharing of benefits arising from the use of crop genetic resources, the ITPGRFA[1] came into force in 2004 and has set out the conditions for access and benefit-sharing in a Standard Material Transfer Agreement (SMTA).

For conserved material to be exchanged, it first needs to be free of pests and pathogens including fungi, bacteria, viruses and insects. Viruses, such as the banana streak viruses (BSV), pose a major risk in the transfer of *in vitro* germplasm. The recently published *Technical Guidelines for Safe Movement of Musa Germplasm 3rd edition* (Thomas 2015) describe procedures that minimize the risk of pest introductions due to the movement of germplasm for research, crop improvement, plant breeding, exploration or conservation (see www.musanet.org).

Photo 4. *The updated Technical Guidelines for the Safe Movement of Musa Germplasm published in 2015.*



1 The International Treaty for Plant Genetic Resources for Food and Agriculture

EVALUATION OF CULTIVARS

At least 56 institutes conserve a total of 15,000 accessions that are potentially available for use by breeders, researchers, farmers or consumers.

Breeders and other researchers require readily available and comprehensive evaluation data to select germplasm for further studies, for use in breeding programs or for testing with farmers and other end-users. Standardized data on agronomic traits, host reaction to pests and diseases and abiotic constraints, post-harvest characteristics and quality (and an integration of the available knowledge) are crucial to help scientists and potential end-users select the right materials.

One of the most significant constraints to the use of banana genetic resources is the lack of publicly available evaluation data for most accessions - even on standard agronomic, quality and physiological traits - and the capacity to manage such data. While having shown its value in the evaluation and adoption of other crops, true participatory cultivar selection is still relatively unexplored in banana.

Photo 5. *Banana market in Sumatra, Indonesia. Credit J. Sardos/Bioversity International*

GENETIC IMPROVEMENT

Genetic improvement presents a potentially cost-effective mechanism to address current constraints in smallholder and commercial production by providing high-performing banana cultivars adaptable to diverse environments. Two basic breeding philosophies have been elaborated by banana breeders: *Evolutionary breeding* and *Pragmatic breeding*. The main breeding programmes considered in the Strategy are CARBAP (Cameroon), CIRAD (Guadeloupe), EMBRAPA (Brazil), FHIA (Honduras) and IITA - NARO (Uganda). The Global Strategy presents information on each of these programmes - including the purpose the hybrids were produced, where they are used, how they are used and prospect for further breeding.

Because genetic improvement of banana is a long-term operation, the relative amount of satisfactory new hybrids is still low, and is not meeting the multiple needs for better alternatives to the local traditional cultivars. In the absence of such alternatives, the farmers need to be assisted in coping with the current biotic/abiotic stresses.

Productivity, resilience and sustainability may be enhanced by integrating crop diversity within production systems. Experience suggests that the risks of losses from epidemic diseases can be mitigated by planting mixed genotypes in place of extensive monocrops of a single cultivar. A demand for increased diversity of cultivars, as well as improved cultivars, exists among smallholder farmers and formal market systems, as well as within the research and breeding community. Supplying producers with a wider range of diversity can potentially enable more livelihood options to be adopted and family nutrition to be diversified.

Photo 6. *Field collection at CARBAP, Cameroon. Credit J. Dongmo/CARBAP*

ACTIONS FOR TOMORROW[2]

TOWARD A REFINED CLASSIFICATION OF *MUSA*

The variation among wild species and subspecies is still poorly known, and there is a need to organise the progressive collection of the complete genetic diversity of wild species. **Studies on newly collected wild diversity** from Indonesia, Myanmar, Indonesian New Guinea and East Africa will work toward this objective.

The **taxonomy of the cultivated subgroups** and of their members needs to be improved. In its present state, a description of a cultivar does not allow for its unequivocal identification and classification at the clone level, meaning that attempts at genetic improvement rely on a too narrow base of existing resources.

Due to the lack of an orderly morphological classification of the numerous edible diploids as mentioned earlier, one objective is to use **standard and reliable molecular marker techniques** for revealing all possible genetic differences (including clusters of same genotypes), and subsequently to **compare this differentiation with the observed cultivars** in order to identify and understand existing subgroups.

Currently the most important tasks concerning triploids are to achieve the **standardized description of all triploid subgroups** and **systematically classify the numerous cultivars per subgroup** via their available descriptions.

2 Key proposed actions highlighted in bold-type

Photo 7. *Some of the Musa diversity conserved at CARBAP, Cameroon. Credit R. Chase/Bioversity International*

UNAMBIGUOUS IDENTIFICATION OF GERMPLASM

The first priority concerning taxonomy of wild relatives is to **fully assess the diversity of *M. acuminata* and *M. balbisiana*** because of its direct and great potential influence on genetic improvement. The second priority is to better understand the ''sections", the first-level classification of all the *Musa* species. To achieve this, collecting missions should take place in diversity hot spots such as Indonesia, North India, Indonesian New Guinea, East Africa and Near Oceania.

The key to determining the subgroups will be the **standardized characterization of the representative cultivars of each subgroup**. The **Taxonomic Reference Collection (TRC) exercise** aims to produce a baseline for the morphological characterization of all edible bananas, i.e. the standardized description of the representative cultivars using multi-locational characterization.

Characterization as a tool for classification of taxa should be markedly improved in order to assess the entire *Musa* diversity. For both the morphological and the molecular characterization, there is a need for clear differentiation of cultivars within the subgroups and this requires the **development of standard descriptor lists for each subgroup**.

For each subgroup, morphological descriptions should be compared with **SSR and DArT genotyping** via discussion between curators and molecular marker specialists in order to reach a consensus.

New molecular techniques will be tested to investigate other approaches (i.e. epigenetics).

STRENGTHENING THE *EX SITU* COLLECTIONS

A long-term goal of the *Musa* research community is that the effective conservation of maximum diversity will be permanently assured through a **functional network of collections** that actively contribute to and benefit from shared standards, strengthened technical capacity, and **effective germplasm and information exchange**.

Among these, there needs to be a **comprehensive assessment of the content of *Musa ex situ* collections towards understanding the gaps and**

Photo 8. *Musa acuminata ssp microcarpa Credit R. Markham/Bioversity International*

priorities. To achieve this, a survey should be carried out to obtain a complete list of the specific accessions conserved in order to create an inventory. Analysis of this inventory would serve as a basis for the identification of gaps and redundancies, after which the gap filling could be prioritized and hotspots for future collection missions identified.

Regional and national collections play a critical role in strengthening the use of the ITC collection. All *ex situ* collections should participate in the completion of MGIS by **providing passport, characterization and evaluation data** on their germplasm. This will facilitate the exchange of knowledge on conservation, the possibility to develop catalogues and raising public awareness on the current conservation and the threats to **Musa** diversity.

The effective conservation of maximum *Musa* diversity will be assured in a permanent manner through **a functional network of collections** that are actively contributing and benefitting from **shared standards, technical capacity, and germplasm and information exchange**. This involves updating standards, publishing technical guidelines and building capacity within collections. National collections should be made more efficient based on **improved characterization**.

This network of partners should have specific responsibilities for conservation of the *Musa* genepool, such as introducing missing diversity to ensure full coverage at national, regional and global level and **identifying core sets of accessions for long-term conservation and safety duplication**. The network should also support the sharing of resources, such as health testing and molecular characterization services in support of conservation and exchange activities. Regional networks should be strengthened

Photo 9. *Measuring a male bud as part of a characterization exercise. Credit J. Dongmo/CARBAP*

through **national and regional workshops and stimulating academic exchange among** national, regional and international centres and genebanks.

Collections have expressed the need for **ensuring that adequate skills and equipment are available**. Particularly important is the need for curators and breeders to ensure the continuity of the collections. Hardware, software and speciality equipment is needed, in particular for *in vitro* and cryopreservation labs, as well as screen houses to back up field collections.

TOWARD MAXIMUM CONSERVATION AND USE OF THE ITC COLLECTION

A 'core' collection of accessions, embodying the total *Musa* diversity, will be **identified and maintained in designated field banks and by *in vitro* storage and backed-up cryopreservation** at the ITC. The core collection will provide evidence of gaps in the collection, contributing to the improvement of conservation. Even though all wild species should be conserved in the national collections of the country of origin or regional collections, a representative of each species should also be made available for exchange through the ITC.

There will be **increased access and targeted use of the ITC collection** through continual improvements to MGIS and the online ordering system. Field verification, morpho-taxonomic characterization, ploidy determination and genotyping of the ITC collection will continue to ensure the genetic integrity and improve the documentation status of conserved accessions. This involves field partners from national collections and research organizations (e.g. Institute of Experimental Botany, Czech Republic), who provide the characterization data needed to add value to the ITC collection. In addition, the ITC needs to take a more proactive approach to collect evaluation data from partners.

It is critically important that the **cryopreservation of the entire ITC collection** is achieved in the foreseeable future. The ITC will also expand long-term conservation capabilities by **investing in seed banking.**

Photo 10. *Loading accessions into the cryopreservation tanks for long term storage at the ITC.*
Credit I. vandenhouwe/Bioversity International

Photo 11. *Garden diversity in Tamil Nadu, India. Credit A. Vezina/Bioversity International*

INCREASING AND OPTIMIZING *IN SITU* AND ON-FARM CONSERVATION

There is a need for **better knowledge of *Musa* wild relatives and of landraces cultivated on farm**. This will allow a prioritization of wild relatives, landraces and landscapes to be conserved.

Frameworks should be developed to **encourage priority *Musa* genetic resource conservation** which would assess different options in terms of *in-situ* and on farm conservation techniques. This would be strengthened by National and International Agreements to allow for the permanent safeguard of protected areas.

Efforts should be made to 1) **link *ex-situ, in-situ* and on-farm conservation practices** in such way that they would be complement each other and to 2) **promote on-farm conservation and utilization of landraces under changing climatic conditions**.

Some wild banana accessions are threatened in *ex situ* collections because they may not be grown in optimum conditions similar to their specific habitat. The best solution is ***in situ* conservation of such taxa and documentation of vital information** such as GPS positions. This calls for a coordinated effort involving national parks and reserves playing a key role.

COMMUNITY-BASED INFORMATION MANAGEMENT

In order to support the core activities of *Musa* collections, it is important to ensure that all collections have access to **appropriate solutions for efficient routine management**. Then, it is essential to **increase data quality, data completeness and facilitate data capture** with modern tools and appropriate standards (e.g. the MusaTab mobile application for easier field characterization).

Other priorities include 1) **complementing accession level documentation with phenotyping and evaluation** data and 2) **integrating genomics and aggregate omics data** generated from germplasm material held in collections.

Photo 12. *Testing the mobile application device for field characterization (MusaTab). Credit J. Dongmo/CARBAP*

The interoperability between MGIS, Banana Genome Hub and breeding resources such as Musabase will facilitate data harmonization.

MGIS will continue to be developed as the banana community portal which includes information on passport data, botanical classification, morpho-taxonomic descriptors, molecular studies, plant photographs and GIS information on various banana collections around the world.

ACCESS TO CLEAN *MUSA* GERMPLASM

Assured access and distribution of *Musa* germplasm will result in benefits for all users, such as increased use of diversity in breeding programmes; knowledge of available traits; sharing of information, technologies and capacity building; reduced duplication of conservation efforts, and increased safety for long-term preservation. An important step towards increased accessibility is that contracting parties of the ITPGRFA indicate the collections that are under their control and in the public domain and make them **available to all users through the use of a material transfer agreement.**

Access to wild and local diversity particularly should be further stimulated and incentives found, such as increased visibility for national collections for sharing the materials and duplicating them in the ITC. There is a need for more exchange of disease-free material between countries within regions. Working toward this goal, regional networks will work to

Photo 13. *In vitro tubes with banana plants for medium term storage at the ITC. Credit N. Capozio/Bioversity International*

strengthen their virus-indexing capacity, by building up *in vitro* collections, optimizing plant conservation and multiplication strategies or equipping collections with virus-indexing kits customized to detect predominant diseases within the region.

Plant health testing methods will be continually improved and updated, and the technology will be transferred to regional laboratories to maximize the health status of collections and facilitate free and safe exchange of germplasm. Also important is to identify key laboratories with expertise in tissue culture to act as **local multiplication centres**.

Disease Factsheets will be updated to increase awareness of the need for, and the advantages of high health status germplasm.

Banana streak viruses (BSV) are the major impediment to the international transfer of germplasm. The ITC will **allow the distribution of accessions with integrated BSV** with the full understanding by the recipient country of relative risks and advantages. This will make more ITC germplasm available to users.

UNDERSTANDING IMPORTANT TRAITS

There is a need to encourage the use of banana genetic resources by different end-users, through the **evaluation of the genepool for traits of interest under diverse environmental conditions**. This includes traits related to abiotic and biotic stresses, and adaptation to climate change. The resulting information and knowledge will be compiled and made available, and important traits highlighted to potential users. The focus will be on traits of global relevance where **cross-regional collaboration and learning is important** and on traits of special importance in regions where high food insecurity and poverty incidence coincides with high importance of banana for food security or income generation.

To capture locally important traits, **gender-sensitive participatory rural appraisal tools** will be used to document the needs and preferences of the different actors along the banana production and value chain. This will achieve a better understanding of underlying factors that determine the value that farmers and consumers attribute to different traits. It will also clarify the criteria that they use for adoption or rejection of cultivars.

A framework will be set up for **data compilation and analysis on AgTrials which will be linked with MGIS and Trait Ontology** in order to share information and knowledge with the broader *Musa* research community and other users/stakeholders.

Photo 14. *Farmer taking banana plants to her field for planting. Credit P. Lepoint/Bioversity International*

ENHANCED UTILIZATION OF *MUSA* GENETIC RESOURCES

Breeding programmes need to **broaden their genetic base** to address the numerous challenges of banana breeding, considering both pests and diseases, fruit quality (organoleptic and post-harvest) and agronomic features (e.g. yield, adaptation to miscellaneous and changing environments).

There is a need to expand the knowledge of fruit quality in parental stocks by **characterizing fruit qualities of diploid germplasm** and fostering **research on the genetics of fruit quality traits**.

The *Musa* genome can now be deeply explored for the characterization of desirable genes involved in important agricultural traits as a prelude to their use in marker assisted selection. Priorities in this area include **improved gene annotation and elucidation of gene function** through analysis of gene expression in specific conditions, mutation/tilling, GM approaches, proteomics and metabolomics.

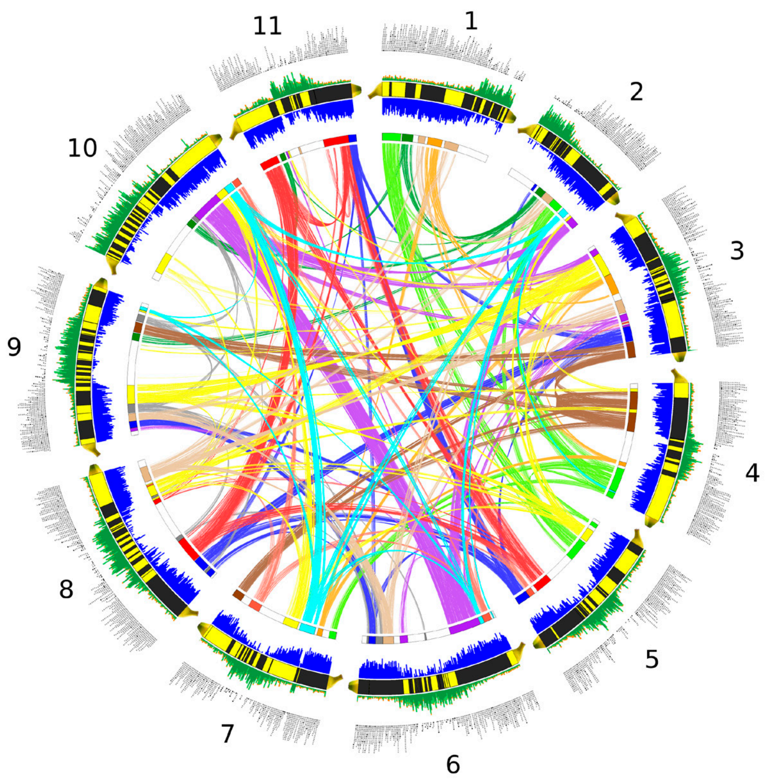


Figure 6. *Circle representation of the banana chromosomes with their associated gene density and ancestral links. Credit: G. Martin/CIRAD*

Overall, pre-breeding should be improved at a global scale by **sharing knowledge and facilitating exchange of genetic stocks of breeding interest.** The evaluation and adoption of improved varieties can be advanced by **establishing a secure network for the evaluation of novel varieties**, such as the International *Musa* Testing Programme (IMTP), including the respect of intellectual property rights of the breeders and by **evaluating hybrids under diverse environmental and cultural conditions**.

THE IMPLEMENTATION OF THE GLOBAL MUSA STRATEGY

MusaNet is committed to overseeing the further development and monitoring of the implementation of the Global Strategy for the Conservation and Use of *Musa* Genetic Resources. The 2016 version of the Global Strategy is therefore the fruit of the efforts of many *Musa* scientists, and conservation and use practitioners, and will be discussed regularly at regional and MusaNet Expert Committee meetings.

With its five thematic groups (Conservation, Diversity, Evaluation, Genomics and Information) and representatives from all major banana-producing regions (Latin America and the Caribbean, West and Central Africa, East and Southern Africa, Asia and the Pacific), MusaNet aims to ensure the long-term conservation of *Musa* diversity on a cooperative basis, and facilitate the increased utilization of *Musa* genetic resources globally. MusaNet encourages international, regional and national public research organizations, development agencies, NGOs and the private sector to use the priorities set out herein to guide their activities and investment decisions.

Full Acknowledgements from the Global Strategy

The Global Strategy for the Conservation and Use of *Musa* (Banana) Genetic Resources, coordinated by the Global *Musa* Genetic Resources Network (MusaNet), is the product of expert opinion and detailed discussions among diverse stakeholders involved in the conservation and use of *Musa* genetic resources since 2011, when MusaNet was established.

MusaNet is grateful to all those involved in developing the first Global Strategy, published in 2006. This 2016 edition builds on the first Strategy and goes beyond the focus on *ex situ* conservation of *Musa* genetic resources to also include priority actions in the areas of *in situ* and on-farm conservation, germplasm evaluation and genetic improvement.

Central to the whole process was Professor Edmond De Langhe who provided scientific leadership. His energy, commitment and dedication to this important exercise are greatly acknowledged.

Brigitte Laliberté, Advisor to MusaNet, coordinated the development of the Global Strategy in close collaboration with Edmond De Langhe and Rachel Chase. We would also like to thank all the members of the MusaNet Expert Committee for their guidance in the process, particularly Nicolas Roux and Jean-Pierre Horry, who contributed to the initial development of the document.

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We consider this Global Strategy a collaborative effort, which could not have been accomplished without the individual and group efforts of many people. We would like to thank all who participated actively in discussions and in the review of the final draft document, which was circulated to all MusaNet members and collection curators. Grateful appreciation is expressed to the lead author and co-author of each Chapter (see list in table below).

This version of the Global Strategy is therefore the fruit of the efforts of many *Musa* scientists, and conservation and use practitioners, and will be discussed regularly at international and regional and MusaNet meetings.

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