PRO MUSA
A Global Programme for Musa Improvement

Proceedings of a meeting held in Gosier, Guadeloupe, March 5 and 9, 1997
Edited by E. A. Frison
G. Orjeda
and S. L. Sharrock
Acknowledgments

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In addition, INIBAP and the World Bank would especially like to thank:
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Contents

<table>
<thead>
<tr>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foreword</td>
<td>5</td>
</tr>
<tr>
<td>Guadeloupe Declaration</td>
<td>6</td>
</tr>
<tr>
<td>PROMUSA - A Global Programme for Musa Improvement</td>
<td>8</td>
</tr>
<tr>
<td>Introduction</td>
<td>8</td>
</tr>
<tr>
<td>Global Programme for Musa Improvement</td>
<td>8</td>
</tr>
<tr>
<td>Guiding Principles</td>
<td>10</td>
</tr>
<tr>
<td>Programme Structure</td>
<td>11</td>
</tr>
<tr>
<td>Programme Strategy and Medium-Term Plan</td>
<td>13</td>
</tr>
<tr>
<td>General Objectives</td>
<td>13</td>
</tr>
<tr>
<td>Specific Objectives</td>
<td>13</td>
</tr>
<tr>
<td>Strategy</td>
<td>13</td>
</tr>
<tr>
<td>Expected Outputs</td>
<td>14</td>
</tr>
<tr>
<td>Working Group Reports</td>
<td>15</td>
</tr>
<tr>
<td>Genetic Improvement Working Group</td>
<td>15</td>
</tr>
<tr>
<td>Sigatoka Disease Working Group</td>
<td>26</td>
</tr>
<tr>
<td>Fusarium Wilt Working Group</td>
<td>32</td>
</tr>
<tr>
<td>Nematology Working Group</td>
<td>41</td>
</tr>
<tr>
<td>Virology Working Group</td>
<td>48</td>
</tr>
<tr>
<td>Global and Regional Evaluation</td>
<td>55</td>
</tr>
<tr>
<td>Annexes</td>
<td>58</td>
</tr>
<tr>
<td>List of Acronyms and Abbreviations</td>
<td>58</td>
</tr>
<tr>
<td>List of Participants</td>
<td>60</td>
</tr>
</tbody>
</table>
Foreword

The first steps towards the establishment of the Global Programme for Musa Improvement (PROMUSA) were taken in 1996, with the aim to bring together, at the global level, all the major efforts in the area of banana and plantain improvement. PROMUSA has been developed jointly by INIBAP and the World Bank through a process of extensive consultation with the various partners and stakeholders and has built upon experience gained from on-going activities such as the INIBAP Breeders' Network initiative and the World Bank Banana Improvement Project (BIP) funded by the Common Fund for Commodity.

As a result of these initial consultations, INIBAP prepared a draft proposal for the programme which was widely circulated as a means to stimulate discussion and to elicit further input into the proposal. This proved to be an extremely fruitful exercise and numerous positive and constructive comments were received. These comments were used to prepare a second draft of the document, which was again distributed by INIBAP to a wider audience. During this period of consultation, the document was distributed to over 50 individuals and institutes, the majority of whom provided feedback for incorporation into the document.

This participative approach led to the production of a final proposal which represented the common views of the interested parties. This proposal was presented for discussion at a joint World Bank/INIBAP meeting which was held in Guadeloupe in March 1997.

The Guadeloupe meeting brought together some 70 of the most prominent researchers involved in Musa improvement worldwide. Discussions of the proposed global programme took place in both plenary and working group meetings. Five Working Groups were formed to address the major research areas, while one group discussed the structure and modus operandi of the programme. At the end of the meeting the creation of a Global Programme for Musa Improvement was strongly endorsed by all participants and a programme structure, modus operandi and medium-term plan were agreed upon.

This document provides details of the strategy and medium term plan for PROMUSA. These include specific objectives for the programme as a whole, for which an initial 10 year period is envisaged, as well as outputs expected by the mid-term point (5 years) and by the end of the 10 year period.

A more detailed strategy and medium term for each Working Group has also been elaborated, in which priority research activities and major constraints are identified and which also includes information on inputs required, expected outputs, indicators and timetables for the achievement of objectives. The Working Group reports also give information on existing facilities and expertise and provide an inventory of on-going research in each specific area.

Finally, proposals for an expanded, more flexible International Musa Testing Programme (IMTP) which has a greater regional focus and which could take on the role of a global and regional evaluation programme, are described.

Emile Frison
INIBAP

Michel Pett
The World Bank
Guadeloupe Declaration

Varieties with increased productivity, suitable for the range of growing conditions under which bananas and plantains are produced, and able to meet the differing local consumer demands, is recognised. It is mainly through genetic improvement that sustainable, environmentally sound, improved production can be achieved.

Advances in banana improvement that have been made in recent years indicate that a high return may now be expected on investment in Musa research. Although the research priorities for commercial and local consumption banana production may differ, there are considerable mutually beneficial “spill-over effects” from research carried out within each sector.

In order to foster close international cooperation and to facilitate the creation of synergies between ongoing research efforts, a global-level initiative is required. Such an initiative should provide the mechanisms through which individual efforts can be globally coordinated as a coherent and prioritized set of activities to more efficiently address critical research needs.

In recognition of the above statement, the creation of a Global Programme for Musa Improvement is strongly endorsed and it is recommended that significantly more resources be directed to Musa research, more particularly in Musa improvement.

Guadeloupe, March 1997
PROMUSA – A Global Programme for Musa Improvement

Introduction

Bananas and plantains are one of the world’s most important yet poorly studied crops. They are grown almost exclusively by smallholder producers, and play an important socio-economic role in many developing countries of the tropics. They are of major importance to food security as well as providing a valued source of income through local and international trade. In terms of gross value of production, bananas and plantains are the fourth most important global food crop. Export bananas are the fourth most important commodity and as a fruit rank first.

The growing recognition over the last 10-15 years of the importance of bananas and plantains has coincided with recent advances in breeding techniques which have made it possible to overcome many of the barriers to genetic improvement of this crop. The number of Musa research and improvement programmes has thus increased considerably in recent years and the first disease-resistant bred hybrids are now being cultivated commercially. However, the genetic improvement of bananas and plantains remains an expensive and slow task, and, considering the scale and diversity of the problems facing banana and plantain growers worldwide, these programmes are still too few in number. Many gaps remain in the knowledge of the major pests and diseases affecting Musa and there is a continuing need to conduct basic plant pathological research. Sources of resistance available to breeding programmes are also limited and these should be widened to avoid the dangers of genetic vulnerability. It is clear that there is still much work to be done before a range of pest and disease resistant varieties, suitable for the varying regional needs and conditions will be widely available. It is only through close international collaboration, drawing together and building on the limited number of on-going initiatives in Musa improvement, that a significant impact will be made in years to come.

Global Programme for Musa Improvement

Considerable progress has been made in recent years by Musa breeding programmes. The first hybrids to be released for general cultivation through the International Network for the Improvement of Bananas and Plantains/United Nations Development Programme (INIBAP/UNDP) International Musa Testing Programme (IMTP) were produced by the Fundación Hondureña de Investigación Agrícola (FHIA) and these are now being tested in national evaluation programmes in more than 50 countries. In some countries these hybrids are already being cultivated on a wider scale by farmers. Similarly, black Sigatoka-resistant plantain hybrids have been developed by the International Institute of Tropical Agriculture (IITA) and these have been widely distributed for evaluation by national programmes in Africa. Further improved hybrids from several breeding programmes are presently being evaluated worldwide as part of the second phase of the IMTP and hybrids from other breeding programmes, including those of IITA, Centre de recherches régionales sur bananiers et plantains (CRBP) and Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), are ready for inclusion in a third phase. INIBAP has also established an informal Musa ‘breeders’ network’, specifically to stimulate cooperation in such breeding efforts.

In parallel, a Banana Improvement Project (BIP), co-sponsored by the Common Fund for Commodities (CFC), the World Bank and the Food and Agriculture Organization of the United Nations (FAO), was set up in 1989 with funding for five years. This project aims to increase the productivity of export bananas, through the development of higher yielding, disease resistant varieties and by reducing the costs of production, especially the cost of pesticide applications. The potential for “spill-over effects” from this project to benefit smallholder producers is great.

The Global Programme for Musa improvement (PROMUSA) has thus been developed as a means to bring together all the major efforts in the area of Musa improvement. It is a broad based programme which links the work carried out towards addressing the problems of export banana producers, including that of the BIP, with those initiatives directed towards improving banana and plantain production at the subsistence and smallholder level. The global programme builds upon existing achievements and is based upon ongoing research initiatives. PROMUSA is therefore a mechanism to further maximize the outputs and accelerate the impact of the overall Musa improvement effort. The programme is an innovative mechanism to bring together research carried out both within and outside the Consultative Group on International Agricultural Research (CGIAR), creating new partnerships between National Agricultural Research Systems (NARS) and research institutes in both developing and developed countries. The formation of such partnerships will also contribute to strengthening the capacity of NARS to conduct Musa-related research.

Recent biotechnological breakthroughs are now allowing rapid progress in Musa improvement and real impact can be expected in the near future. PROMUSA therefore, in the initial stage, is focusing specifically on research directly related to Musa improvement. Wide participation in the programme ensures that PROMUSA has a global perspective and the structure is such that ownership of research is broadly based. A global and regional evaluation programme operates in parallel to the improvement research activities allowing NARS, and subsequently farmers, easy access to improved material as it is produced. The evaluation programme not only provides a mechanism for the rapid dissemination of research results to farmers, but is also a channel through which information from farmers is fed back into the programme.

It is recognised that issues related to intellectual property rights and biosafety regulations have profound implications for programme implementation and these will need to be addressed within the framework of PROMUSA.

Funding which becomes available to the programme will be channelled to priority activities through a number of mechanisms including competitive grants and specific contract research grants.
Guiding Principles

- The Global Programme for Maize Improvement will focus specifically on genetic improvement and supportive research and priority will be given to research which has a global or regional significance.

- PROMUS will operate as a consortium and will rely on a range of funding mechanisms.

- Partners in the programme are expected to contribute in-kind their own research and, in addition, the programme seeks further resources in order to address priority research needs, as identified by the programme partners.

- PROMUS’s organizational structure will be simple and efficient in order to ensure that maximum support is maintained for research activities.

Programme activities take place in a series of thematic working groups, which allow continual interaction between group members. Interdisciplinary contact also occurs at regular intervals through meetings at the programme level and on a continuing basis through the programme secretariat.

Thematic working groups operate as networks, thus the formation of collaborative projects between group members, resulting in a division of labour and the creation of synergies is facilitated. Networking as a modus operandi not only fosters collaboration between network partners but also provides an efficient mechanism for priority setting and facilitates the regular flow of information between network members.

- Participation in PROMUS will be based on the capacity to contribute through a high scientific capability in maize research and on comparative advantage and will be on a voluntary basis.

- Decision making within PROMUS will follow a bottom-up approach and participating scientists will be fully involved in this process.

- Decisions are based on scientific priorities identified by programme participants and based on user needs. The global and regional Maize evaluation programme plays a major role in this regard, providing a mechanism for the two-way exchange of information between NARS and research and breeding programmes. The provision of feedback information regarding farmers’ needs is of particular importance in setting research priorities. The existing global maize research networks also provide a useful channel through which information from national programmes is fed back to the global programme.

- Partners in PROMUS will benefit from:
  - global prioritization of research needs;
  - improved possibilities for funding for programme participants due to recognition of the programme by donor agencies;
  - close interactions with, and knowledge of, other research teams within their area of specialization;
  - opportunities for interdependent research projects (i.e. projects requiring interdisciplinary and complementary partnerships);
  - improved access to information and resources;
  - participation in programme meetings and conferences.

Programme Structure

The programme operates as a series of interlinked thematic working groups coordinated by an Executive Secretariat. The programme is directed by a Steering Committee and operates under a Programme Support Group. Further details of the programme structure are given below.

Programme Support Group: This is composed of major donors and stakeholders and thus comprises representatives from donor agencies (e.g. countries, International Fund for Agricultural Development (IFAD), CFC, UNDP, World Bank, Foundations, private sector); other relevant organizations (e.g. FAO and the Inter-governmental Group on Bananas); representatives of Advanced Research Institutes (ARIs), International Agricultural Research Centres (IARCs) and NARS. Membership is also open to other interested parties. The Programme Support Group provides visibility, guidance and support to the programme. It endorses the overall direction and strategy of the programme and contributes to identifying and providing additional funding and other resources as necessary.

Steering Committee: The Steering Committee comprises representatives from NARS, ARIs and IARCs. In addition, the Chair of the Programme Support Group attends the Steering Committee meetings as an observer. This committee is responsible for proposing direction and providing oversight to the programme. It sets priorities based on technical advice from the working groups compiled by the Executive Secretariat and advises donors on the allocation of resources to the programme. The Steering Committee also approves the programme strategy, medium-term plan and annual workplan. It commissions reviews of the programme, advocates on behalf of the programme and seeks external technical advice as appropriate.

Executive Secretariat: The Executive Secretariat is provided by INIBAP. It serves as the programme coordinator and is responsible for ensuring the smooth running of the programme as well as providing a programme secretariat. It also facilitates the organization of technical meetings, both thematic and interdisciplinary, and disseminates information to programme partners. It prepares reports and compiles lists of priorities, based on technical advice provided by the thematic working groups. Internal communication is a particularly important aspect of the programme, and the Executive Secretariat plays a critical role in stimulating contacts between groups.

Regular inter-group information exchange is ensured through a programme newsletter, which is either published separately or included as a "PROMUS" section in an existing newsletter. The Executive Secretariat also has an important role to play in providing feedback to the programme and ensuring a link with the end-users. The Executive Secretariat can also, if required, play the role of executing agency for funding provided to the programme.

Thematic working groups: The working groups are the heart of the programme. The members of these groups implement the programme workplan through a project portfolio which includes projects carried out by individual participants as well as collaborative projects involving a number of participants funded through various
Programme Strategy and Medium Term Plan

General Objectives
1. To increase the productivity of bananas and plantains produced for home consumption and local and export markets in an environmentally sustainable manner.
2. To facilitate the development of improved Musa varieties with a wide genetic base, and consumer acceptability and to disseminate these varieties to farmers through participating NARS.
3. To facilitate and stimulate partnerships among NARS, advanced research institutes, and IARCs to increase the efficiency and cost-effectiveness of global Musa improvement efforts.

Specific Objectives
- To obtain the necessary basic scientific information to enable the production of a wide range of genotypes resistant to the major nematode pest species and to Sigatoka and Fusarium diseases.
  - Identification of sources of resistance - nematodes, Sigatoka, Fusarium;
  - Better knowledge of the types of resistance to nematodes, Sigatoka and Fusarium and an understanding of the inheritance of these traits;
  - Information on pathogenic variability and geographic distribution of major nematode pest species and of the Sigatoka and Fusarium fungi.
- Development of efficient breeding methodologies.
  - Broadened genetic base of material used by breeding programmes;
  - Identification of molecular markers and their use in marker-assisted breeding;
  - Development of biotechnological tools;
  - Integration of conventional breeding and biotechnology methodologies.
- Control of viruses in Musa.
  - Development of robust diagnostic systems for the major viruses affecting Musa in order to facilitate germplasm movement;
  - Production of transgenic virus-resistant clones.
- Evaluation and dissemination of improved varieties through a global and regional evaluation programme.

Strategy
The production of improved, farmer acceptable, Musa varieties through the development and application of conventional and biotechnological breeding approaches, incor-
porating resistance to pests and diseases to increase productivity and reduce pesticide use, operating in an environment in which collaborative partnerships and close interactions are fostered.

Expected Outputs (5 years)

- New sources of resistance/tolerance to nematodes, Fusarium and Sigatoka identified and being used by breeding programmes;
- Fusarium and Sigatoka resistant varieties produced by conventional breeding approaches;
- Disease resistant hybrids of various types, including export bananas, plantain, Silk-type, Pome-type, cooking bananas, etc. being evaluated in multi-locational trials;
- Knowledge on the extent of adaptation of varieties that have passed through the evaluation programme;
- Database of agronomic and resistance/tolerance characteristics of the main varieties;
- Improved diploids available to breeding programmes;
- Molecular markers available for marker-assisted breeding schemes;
- Resistance constructs for banana bract mosaic virus (BBMV), banana bunchy top virus (BBTV) and cucumber mosaic virus (CMV) developed;
- Diagnostic tests available for most major viruses including latent infections of BBTV;
- Basic information on banana streak virus (BSV) system for use in developing transgenic resistant plants;
- Efficient genetic transformation methods;
- Better understanding of host/pathogen relationships and mechanisms of resistance to nematodes, Fusarium and Sigatoka;
- Information on relationship between *Musa* varieties and various components of yield loss caused by nematodes;
- Fusarium and Sigatoka pathogenic diversity clarifed.

Expected Outputs (10 years)

- *Fusarium/Sigatoka* resistant clones developed through conventional and transgenic approaches;
- Nematode resistant clones developed through conventional and transgenic approaches;
- Virus resistant clones developed through transgenic approaches;
- Range of improved germplasm, with broad genetic base, available to NaBS and farmers;
- Early screening tests developed;
- Resistance genes identified;
- More molecular markers available for marker-assisted breeding schemes.

Working Group Reports

Genetic Improvement Working Group

1. Scope of Work, Priority Research Needs and Major Constraints

It was noted that recent advances in the genetic improvement of *Musa* have been significant, with several hybrids of dessert banana, plantain and cooking banana being evaluated in many countries. Some of these hybrids have recently reached the stage of commercial production and marketing in a few countries.

Additional funding for on-going improvement efforts has therefore the potential to greatly enhance the production and release of better cultivars, both for the world export market and for the local consumption and market scenario.

1.1 Scope of work

To produce improved *Musa* varieties through the integrated use of classical and biotechnological breeding approaches. In relation to classical breeding, the emphasis will be on research to improve the efficiency of breeding, including the development of marker-assisted breeding schemes, as well as on the enhanced utilization of plant genetic resources by breeders and on the greater exchange of breeding materials between breeders. In relation to genetic engineering, the scope of work is to develop efficient and transferable or generally accessible molecular biology and plant gene transfer tools for generating genetically modified bananas. Possible methods identified are: transformation techniques through particle bombardment, *Agrobacterium tumefaciens* or protoplast electroporation as well as protoplast fusion techniques.

1.2 Priority research needs

For the identification of priority research needs the Genetic Improvement Working Group divided into two sub-groups: The Breeding and Genetics sub-group and the Genetic Engineering sub-group.

(1) This report was prepared as a result of meetings held in Guadeloupe in which the following participants were involved: F. Baker (CIRAD), G. Barord (CIRAD), S. Ghoulam (RTI), S. Gile (ANTEC/CIRAD), E. Delapraz (CIRAD), J. Debeaujon (INRIA), J. P. Hesley (INRIA), C. J. Heron (CIRAD), D. Kriger (IFRA), B. L. Le Brust (INRIA), B. Nael (SVO), S. de Oliveira (EMBRAPA), G. Deo (INRA), A. Pires da Mota (EMBRAPA), P. Rowe (IFIA), J. Siqueira (ICBA), M. Smith (QIP), C. Swann (ICBA), R. Tomes (ICBA), D. Venn (IFIA). In addition, the following scientists were consulted subsequent to the Guadeloupe meeting: R. Orono (Banana Board of Jamaica), S.C. Hwang (TBIR), P. Lagoda (CIRAD), M. Malanquart (IAEA), G. May (RTI), H. F. Singh (NRDC), H. Torres (CIRAD), A. Visser (ARC-FAO), C. Viallon (CIRAD) and J. Zapata (IAEA).
Breeding and genetics sub-group
An integrated approach to genetic improvement requires that all activities in the scope of the work should be undertaken. The highest priorities have been identified as follows:
- Enhanced utilization of plant genetic resources by breeding programmes;
- Exchange of breeding materials and information;
- Research into efficient breeding methodologies;
- Marker assisted selection.

- Enhanced utilization of plant genetic resources by breeding programmes
  Breeders need better access to existing Musa collections for increased availability of natural germplasm. Where gaps are identified in these collections, targeted exploration and collection of germplasm should be considered, with a particular focus on wild species. Such exploration should be coordinated by INIBAP/IFGRL. To improve access to existing collections, more effort should be put into good characterization of the germplasm and the ensuing databases/ information should be exchanged among collections and breeders. Existing working collections should also be supported in their germplasm conservation efforts.
  This activity will result in a broader germplasm base in breeding programmes.

- Facilitation of the exchange of breeding materials
  Breeders' materials at various stages of improvement and of varying ploidy should be exchanged more vigorously among breeders. This can be facilitated by a better characterization of such materials and the exchange of information (including breeders' notes on combining abilities). This activity also requires faster and easier, but reliable virus diagnostics, which should be achieved both by increasing the INIBAP/Virus Indexing Centers (VICs) capacity and by decentralizing pathogen testing for regional germplasm movement.

- Research into efficient breeding methodologies
  Various schemes and approaches to genetic improvement should be tested to make banana breeding more efficient and to strengthen overall breeding efforts in order to better address national and regional needs.
  - Investigations into the genetics of important traits, e.g. disease/pest resistance and quantitative traits.
  - Marker assisted selection, particularly for screening of traits that are difficult or slow to evaluate, as such increasing the efficiency of breeding and selection.
  - Multilocalional evaluation of germplasm to investigate genotype-by-environment interaction and to determine the stability of important traits.
  - Research into somaclonal variation and mutation induction as tools for genetic improvement, including the molecular analysis of the basis of somaclonal variation.

- Marker assisted selection
  Research related to molecular markers links with the work carried out by the genetic engineering working group. The following research areas are therefore applicable to both groups:
  - Molecular mapping for marker assisted selection to identify single genes and genome segments for use in transformation of cultivars and breeding materials.
  - Development of efficient recombinant DNA techniques for isolation and introgression into Musa of genes covering a wide array of desirable traits.

Genetic engineering sub-group
- Transformation protocol (development of efficient transformation systems, including upstream and downstream tissue culture activities)
  Development of pre-transformation tissue culture systems, which do not cause somaclonal variation, for the different varieties of interest. This would include investigations into genotype effect on the development of cell suspensions and the development of meristem cultures with a high capacity for regeneration.
  Development of reliable constructs for transformation.
  Development of a molecular tool box for controlled gene expression.
  Priority ranking: High

- Availability of promoters
  There is a need to identify all kinds of strong promoters for transgene expression, including promoters that can be obtained from banana plants.
  Priority ranking: High

- Molecular genetics
  - Gene mapping;
  - Library construction (Bi-RAC);
  - Comparison of sequence homology between genotypes;
  - Cloning genes of important traits;
  - Transposon-tagging and T-DNA-tagging;
  Priority ranking: High

- Selection markers, alternatives to antibiotics
  Priority ranking: Medium

- Development of early in vitro selection methods/medias for identifying somaclonal variants with interesting traits.
  Priority ranking: Medium

- Development of in vitro early mutagenesis for producing plants with interesting traits.
  Priority ranking: Low.

1.3 Major constraints
- Short-term nature of funding: this is of particular relevance to genetic improvement programmes, which are expensive and time-consuming and require continuous support on a long-term basis.
- Inadequate linkages between genetic engineering and conventional breeding programmes: these links need to be improved and facilitated especially for:
  a. evaluation of transgenic products in the field
  b. transformation of breeding lines
2. Research Strategy

The working group recognizes that there are a number of approaches for the improvement of Musa:
- Breeding
- Genetic engineering
- Mutation

The group recognizes that the best strategy to strengthen Musa improvement is through the close integration of classical and genetic engineering breeding approaches and through the sharing of breeding material and knowledge among group members.
- The Executive Secretariat should facilitate the exchange of material and information;
- The different groups need to improve their tools, particularly in relation to the further development of marker assisted selection;
- PROMUSA should establish "resource centres" from which material could be obtained for genetic improvement research (e.g. cell cultures, libraries, vectors, Agrostrains etc.).

3. Areas for Collaboration

- Germplasm evaluation, including multilocational trials, such as IMTP.
- Marker assisted selection, exchange of markers.
- Integration of biotechnology and conventional breeding programmes, including testing of transgenics.

3.1 New areas for collaborative research

- Integration of somaclonal variation and conventional breeding.
- Information on available germplasm and breeding materials.
### Genetic engineering sub-group

<table>
<thead>
<tr>
<th>Institute</th>
<th>Transformation protocol</th>
<th>Promoters</th>
<th>Mapping</th>
<th>Gene cloning</th>
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A list of acronyms and abbreviations is provided at the end of the document.
X: have the relevant expertise in their domain; XX: have already obtained positive results.

### 4.2 Inventory of on-going research

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<thead>
<tr>
<th>Institute</th>
<th>On-going activity</th>
<th>Expected output</th>
<th>Time frame</th>
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<tbody>
<tr>
<td>FIA, Honduras</td>
<td>Breeding for replacement for the Cavendish export banana</td>
<td>One, or more, black Sigatoka- resistant, dwarf hybrids with export qualities. This is being done by crossing disease-resistant, agronomically improved line derivatives onto the Lowgate dwarf mutant of Gros Michel. Development of the FIA-01 banana has shown that this 3X x 2K approach to genetic improvement is effective.</td>
<td>5 years</td>
</tr>
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<td></td>
<td>Breeding for dwarf, disease-resistant plantains</td>
<td>One or more hybrids with the desired characteristics. Development of the FIA-21 plantain hybrid has validated the approach being employed in plantain improvement.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Breeding for dwarf, disease-resistant cooking bananas</td>
<td>One or more hybrids for evaluation in East Africa. The FIA-03 cooking banana already developed in this breeding objective is being cultivated commercially in Cuba.</td>
<td>5 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Institute</th>
<th>On-going activity</th>
<th>Expected output</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITA, Nigeria</td>
<td>Enhanced Musa germplasm utilization</td>
<td>Germplasm with desirable alleles available and used. Main focus is on ideotype breeding and multi-tail selection, and population improvement based on combining abilities. Desirable traits include Sigatoka, virus, nematode, Fusarium, weevil resistance, better root systems and good fruit quality.</td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Improved plantain and banana genotypes and populations</td>
<td>At least 10 improved genotypes tested in multi-localizations 4 years trials in at least 8 African countries. The breeding approach includes conventional and non-conventional cross-breeding, poly-cross breeding, varietal mixtures, and international dissemination of improved genotypes. Hybrids should include high and stable yield, resistance/tolerance to biotic and abiotic stresses, desirable plant habit, and good fruit quality.</td>
<td></td>
</tr>
<tr>
<td>EMBRAPA, Brazil</td>
<td>Breeding for dwarf, disease and pest resistant bananas (including Moko resistance)</td>
<td>One or more hybrid (Pome-type) resistant to black and yellow Sigatoka. One or more Fusarium resistant Silk hybrids. One or more hybrids resistant to Moko. All hybrids tested under farmers field conditions.</td>
<td>5 years</td>
</tr>
<tr>
<td>CRBP, Cameroon</td>
<td>Plantain improvement by 3X x 2K -&gt; 4X</td>
<td>Dwarf plantain hybrids with resistance to black Sigatoka and R. similis, virus indexed and evaluated in multi-localation trials in West and Central Africa. Improved plantain-like male parental lines developed and tested.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Production of Plantain hybrids by 2X -&gt; colchicine New crosses ABAB x AA or BB.</td>
<td>Improved 3X plantain hybrids tested in multi-localation trials in West and Central Africa. (Collaboration with CIRAD)</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>(Collaboration with CIRAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diploid improvement for improved plantain-like parental breeding lines</td>
<td>Creation of disease and pest resistant plantain-like AB hybrids (BB x AAcw) for the triploid breeding scheme ABAB x AAcw.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Germplasm characterization</td>
<td>About 400 natural accessions evaluated for agronomorphologic traits, fruit quality and resistance to disease and pests.</td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Plantain improvement by tetraploid breeding</td>
<td>Selection of 10 or more tetraploid plantain hybrids resistant to BLS and other parasites for global and regional evaluation.</td>
<td>3 years</td>
</tr>
<tr>
<td>Institute</td>
<td>On-going activity</td>
<td>Expected output</td>
<td>Time frame</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>CRBP Cameroon</td>
<td>Diploid improvement</td>
<td>Twenty or more resistant plantain and cooking-type AA and AB for tetraploid and triploid breeding.</td>
<td>3 years</td>
</tr>
<tr>
<td>(cont'd)</td>
<td>AAB triploid breeding</td>
<td>10 or more plantain and cooking-type hybrids resistant to disease and pests available for global and regional evaluation.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Formal genetics</td>
<td>Four or more diploid segregating populations. Better knowledge of the genetics of resistance and major agronomic traits.</td>
<td>3 years</td>
</tr>
<tr>
<td>CIRAD France</td>
<td>Triploid breeding: production of AAA and AAB dessert bananas</td>
<td>Creation of triploid hybrids resistant to BLS, YS, R. similis and Foc for exportation and local market in different countries.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Enhanced Musa germplasm characterization and utilization</td>
<td>Development of a database. Precise identification of the relationships between cultivated triploids and related diploids.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Genetic mapping</td>
<td>Research of QTL. Identification of genes of agronomic interest coming from banana genomes.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Banana Board Jamaica</td>
<td>Breeding varieties suitable for food and commercial production.</td>
<td>Varieties (tetraploid) resistant to black Sigatoka are being crossed by diploids 4X x 2K and 4X x 2X. One very promising triploid has been produced so far. Continuation of this approach seems to be on a progressive path.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td>Tetraploids and triploids resistant to black Sigatoka, Foc and nematodes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CATIE Costa Rica</td>
<td>In vitro regeneration methods</td>
<td>In vitro cryopreserved cell suspension from different cultivars.</td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Methods of transformation</td>
<td>Efficient methods of transformation.</td>
<td>3 years</td>
</tr>
<tr>
<td>HKUST Hong Kong</td>
<td>Completion of sequencing two ACO and two ACS genomic DNA clones.</td>
<td></td>
<td>2 years</td>
</tr>
<tr>
<td></td>
<td>Study of the differential regulation of the gene expression of ACO and ACS.</td>
<td></td>
<td>2 years</td>
</tr>
<tr>
<td></td>
<td>Subcloning of the promoters that confer fruit or leaf specificity.</td>
<td></td>
<td>2 years</td>
</tr>
<tr>
<td>University of Hawaii USA</td>
<td>Agrobacterium meristem transformation system</td>
<td>Efficient and reliable systems.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gene gun/cell suspension transformation system</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Embryogenic callus transformation system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIRAD France</td>
<td>In vitro regeneration and gene transfer method</td>
<td>Efficient methods of transformation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Genetic engineering/mapping/gene cloning</td>
<td>Better knowledge of the origin and genetic bases of the resistance/synergies of interest.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Genetic engineering (particle bombardment, Agrobacterium transformation)</td>
<td>Transformed plants with exogenous genes expressed with improved agronomic/pest-disease resistance traits.</td>
<td>1997 onwards</td>
</tr>
<tr>
<td>BTI USA</td>
<td>Structural genes from banana. Promoter characterization</td>
<td>Constructs for tissue-specific expression in banana. Bi-Bac library construction.</td>
<td>2 years</td>
</tr>
<tr>
<td>ARC-ITSC South Africa</td>
<td>In vitro regeneration methods</td>
<td>Efficient and reliable systems for regeneration.</td>
<td>2 years</td>
</tr>
<tr>
<td></td>
<td>Method of transformation</td>
<td>Gene gun.</td>
<td>2 years</td>
</tr>
<tr>
<td></td>
<td>In vitro evaluation for cold tolerance</td>
<td></td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td>Nursery evaluation for Fusarium resistance</td>
<td></td>
<td>On going</td>
</tr>
<tr>
<td>John Innes Centre UK</td>
<td>AFLP mapping</td>
<td>Technique is currently up and going in many crops, e.g. cereals, yams, cowpeas, other legumes etc. and is being applied to BSV integration.</td>
<td></td>
</tr>
</tbody>
</table>
## Medium-Term Plan

<table>
<thead>
<tr>
<th>Goal</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production of pest and disease resistant hybrids</td>
<td>Germplasm. Equipment and expertise. Evaluation information on populations and hybrids.</td>
<td>Segregating populations. Improved hybrids.</td>
<td>Improved hybrids available to farmers.</td>
</tr>
<tr>
<td>Identification of selection markers</td>
<td>Equipment and expertise.</td>
<td>Identification of selection markers as alternatives to antibiotics.</td>
<td></td>
</tr>
<tr>
<td>Identification of molecular markers</td>
<td>Equipment and expertise.</td>
<td>Molecular markers for identifying traits of interest.</td>
<td>Molecular markers used in breeding.</td>
</tr>
</tbody>
</table>
Sigatoka Disease Working Group

1. Scope of Work, Priority Research Needs and Major Constraints

1.1 Scope of work

Sigatoka leaf spot diseases of bananas involve two related pathogenic ascomycete fungi: *Mycosphaerella fijiensis* Morelet causing black leaf streak disease (BLSD) and *Mycosphaerella musica* Leach ex. Mulder, causing Sigatoka disease (SD). *M. fijiensis* is characterized by its stronger pathogenicity on a broader range of hosts, making BLSD the most destructive leaf disease of bananas (AAA), plantains (AAB) and other cooking bananas.

Research on BLSD is required in order to develop effective strategies to maintain the production of bananas and plantains and is of the highest urgency. Integrated solutions are needed, including the selection of resistant clones, cultural practices and rational chemical control. Because of the widespread nature of the problem, it is necessary to focus on research in the following areas in close collaboration with breeding programs.

- a. Expansion of knowledge on the types of resistance expression (phenotypes);
- b. Assessment of pathogenic variability and distribution of pathogenicity of *M. fijiensis* and *M. musica*;
- c. Identification of new sources of resistance;
- d. Development of screening methodologies for resistance to black leaf streak and Sigatoka disease (inoculation under controlled conditions, biochemical markers, screening using toxins);
- e. Determination of the status of Sigatoka diseases in some areas, mainly in Asia;
- f. Identification of the different gene interactions during the polycyclic disease development (components of resistance) through epidemiological studies;
- g. Improvement of disease evaluation methods to improve the accuracy of the assessment of resistance phenotypes.

1.2 Priority research needs

Pathogenic variability of the pathogens

Since BLSD has a perfect stage, recombination of genes can occur inducing the appearance of new pathotypes. The geographical genetic diversity of *M. fijiensis* at the global level has already been investigated. However, there is some evidence for the existence of pathogenic variability as well. It is therefore essential to have a better understanding of the structure of pathogen populations in order to make the genetic improvement of bananas more efficient and for the resistance to be durable. Research in the following areas is necessary:
- estimation of the extent and distribution of genetic variability within *M. fijiensis* and *M. musica* populations using molecular markers (neutral markers) and to relate this information to pathogenic variability;
- quantification at the greenhouse level of the extent of pathogenic variability of the two pathogens by using a differential set of Musa cultivars (pathotypic markers). A set of pathotypes that represent the full pathogenic diversity of the pathogen populations will be selected in terms of "virulence and aggressiveness";
- detection at the field level in several areas the presence of pathogenic strains by planting large plots of selected or reference materials used as a source of resistance to maintain a greater selection pressure.

Development of early screening methods

The following strategies are suggested for research:

- Artificial inoculation under controlled conditions

Inoculation procedures must be available for assessing qualitative (highly resistant) as well as quantitative (partially resistant) expressions of resistance using a set of pathotypes that represent the full diversity of the pathogen (pathogenicity/aggressiveness in populations).

Inoculation procedures to assess qualitative (vertical) resistance are simple and do not require rigorous control of inoculum and incubation conditions. On the other hand, for quantitative (horizontal) resistance, inoculum level, host age, and incubation and post-inoculation conditions must be strictly controlled. Artificial inoculation should not be so severe as to overestimate the capacity of an agent to cause disease or to under-estimate the resistance of the host. Factors to be assessed will include:
  1. qualitative and quantitative differences in susceptibility;
  2. quality of inoculum (type, age, concentration of conidia, etc.);
  3. physiological age of acclimated viroplantelets;
  4. environmental conditions prior to, and especially after inoculation.

The correlation between the behaviour of young material in controlled conditions (growth cabinets/glasshouse) and the behaviour of mature plants in the field will be evaluated in using a set of reference banana cultivars already characterized for the field reaction to BLSD and SD.

- Use of toxins produced by *M. fijiensis*

The role of toxins in pathogenicity remains unclear, therefore, research aimed at clarifying this relationship is important before toxins can be used for screening germplasm. Research is required in order to:
  - investigate the relationship between the level of the resistance to the infection (under natural field inoculation) and the sensitivity to the toxic compound produced *in vitro* by *M. fijiensis*. 

---

(1) This report was prepared as a result of meetings held in Guadeloupe in which the following participants were involved: A. Fagan (WIDERCO), R. Pousin (CIRAD), X. Morellec (CIRAD), A. L. de Matos (EMBRAPA), R. Romero (CORBANA), S. Tripon (INIBAP), P. V. Nai (MAP). In addition, the following scientists were consulted subsequently to the Guadeloupe meeting: R. Fullerton (Host Research), A. Johnson (NRI), R. Peterson (QPL), and W. Tshumavinde (NABO).
compare of the behaviour of intact plants towards the toxins (detached leaf assays) and the sensitivity of banana tissue expressed in vitro (callus and cell suspensions). The results will be used to develop an appropriate screening technique. The toxins can be applied to detached leaves of plantlets or tissue cultured in vitro (callus, cell suspensions, protoplasts), if it is confirmed that toxin tolerance will be expressed in the regenerated plants.

New sources of resistance
It appears to be necessary to look for new sources of resistance in areas where host and pathogen co-evolution have been demonstrated (Southeast Asia).

Epidemiological studies
Sigatoka diseases are characterized by being poly cyclic. Resistance in the host results from the effect on different components of the disease. It is essential to assess the weight of each epidemiological sequence (each gene interaction) in the resistant phenotype. These elements will be very useful for molecular mapping (QTL approach).

1.3 Major constraints
• Lack of expertise in many areas (relatively few institutes working on this disease)
• Insufficient infrastructure
• Need for integration of plant pathology with breeding programmes.

2. Research Strategy
(a) Select a coordinator to identify possible collaborators for research in the following three main areas:
  • mechanisms of resistance
  • pathogen variability
  • epidemiological studies.
(b) Bring the collaborators together to identify their potential contributions in the collaboration and develop research proposals in each area. The coordinator will identify which aspects of the proposals would require funding. The group should be open to additional collaborators with expertise as needed.

3. Areas for Collaboration
For the evaluation of pathogenic variability, collaboration is sought between banana producing countries (Costa Rica, Cameroon, Philippines, Tonga) and banana non-producing countries where this is possible because of quarantine regulations. To obtain a large collection of M. fijiensis and M. mravincei isolates with good coverage of the different production zones (Southeast Asia, Pacific, Africa and Latin America), the working group propose:
• Close collaboration among all interested partners in supplying isolates, that will be further characterized for pathogenicity virulence or aggressiveness.

• Collaboration is also sought to conduct field trials in the four main areas, where genetic structure of M. fijiensis is already demonstrated (Southeast Asia, Africa, Latin America, Pacific) to detect pathogenic strains and host-parasite specific interactions (using reference banana clones). At this level, some areas of collaboration between Bureau of Plant Industry (BPI, Philippines), CRBP (Cameroon), Corporación Nacional (CORPANA, Costa Rica) and Ministry of Agriculture and Forestry (MAF, Tonga) can be expected.

The collaboration between CIRAD, University of Gembloux and CRBP should continue and be strengthened in order to increase knowledge on resistance mechanisms. Similar studies on pathogenic variability and resistance mechanisms can be conducted for M. mravincei through collaboration between Australia (QDPI), Brazil (EMBRAPA), Caribbean (WIBEDCO, St Lucia).

3.1 New areas for collaborative research
• Role of toxins in the pathogenicity of both pathogens: Mycosphaerella fijiensis and Mycosphaerella mravincei
• Mechanisms of host resistance.

3.2 Identification of research needs requiring inter-group collaboration
Stronger and continuous collaboration is needed between the Sigatoka working group and the Genetic Improvement group. The main areas of collaboration could be as follows:
• Identification of new sources of resistance, mainly at the diploid level. Screening in controlled conditions will allow the selection of lines for resistance by using pathotypes which represent the full diversity of pathogen populations.
• Improved accuracy of assessment methods for the inheritance of BLSD thus allowing a component of the disease cycle, i.e. gene interaction between the host and the parasite, to be distinguished. Such information is essential to map the genes involved in partial resistance (QTL work).

Interaction with the IMTP group is necessary to provide useful indications for a more appropriate selection of IMTP sites (acording to the pathogenic structure).

4. Inventory of Existing Facilities, Expertise and On-going Research
4.1 Existing facilities and expertise

<table>
<thead>
<tr>
<th>Expertise Lab.</th>
<th>Staff</th>
<th>Field</th>
<th>Greenhouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIRAD, France</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>CORPANA, Costa Rica</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>CRBP, Cameroon</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>EMBRAPA-CNPM, Brazil</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>MAF, Tonga</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>WIBEDCO, Windwards Islands</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

A list of acronyms and abbreviations is provided at the end of the document.
## Medium-Term Plan

<table>
<thead>
<tr>
<th>Goal</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Indicators</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pathogenic variability of pathogens</td>
<td>Expertise and equipment. Molecular markers.</td>
<td>Provision of criteria for selection of appropriate field testing sites for resistance. Basic information on the pathogen.</td>
<td>Field sites being used for screening. Availability of molecular markers. Set of pathotypes available.</td>
<td>5 years</td>
</tr>
<tr>
<td>Early screening</td>
<td>Equipment and expertise. Source of high quality plantlets. A set of pathotypes that represent the full pathogenic diversity of the pathogen.</td>
<td>A methodology for early screening of resistance useful to breeding programmes. Correlation between greenhouse behaviour and field behaviour. Clarification of role of toxins in pathogenicity.</td>
<td>Sources of resistance being used by breeders.</td>
<td>5-10 years</td>
</tr>
<tr>
<td>New sources of resistance</td>
<td>Collecting missions in Southeast Asia.</td>
<td>New sources of resistance available to breeders. Widened genetic base of resistance.</td>
<td>Sources of resistance being used by breeders.</td>
<td>5 years</td>
</tr>
<tr>
<td>Epidemiological studies</td>
<td>Expertise and equipment.</td>
<td>Understanding of host-pathogen relationships.</td>
<td></td>
<td>5-10 years</td>
</tr>
<tr>
<td>Status of Sigatoka disease in Asia</td>
<td>Surveys. Collecting missions.</td>
<td>Information on the relative importance of black and yellow Sigatoka throughout Southeast Asia.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fusarium Wilt Working Group

1. Scope of Work, Priority Research Needs and Major Constraints

1.1 Scope of work
The Fusarium Wilt Working Group will continue to concentrate on the assessment of genetic and pathogenic diversity in Fusarium oxysporum f. sp. cubense (Foc) and on surveying the geographic distribution of genetic and pathogenic variants of the pathogen. Efforts will be made to identify additional parents which resist Fusarium wilt, especially tropical race 4 (VCG:01215203216), as well as advanced hybrids of the different types (e.g. sweet acid, dessert, export, dessert, etc.). Where appropriate segregating populations of the host and sufficient resources exist, marker-assisted selection will be investigated. Work will also be carried out to investigate why tissue cultured plantlets are more susceptible to this and other diseases and the means by which their vigour can be enhanced.

1.2 Priority research needs

Early screening test
The ability to score Foc isolates for virulence on different banana clones and different clones for resistance to pathotypes of Foc would assist the breeding programmes and allow the informed deployment of germplasm to various producing regions. Expansion of existing facilities and resources would allow significant research in this area to be conducted.

Field screening of parents and clones
Field screening has been and will likely continue to be the primary means by which resistance is identified for the near future. Moreover, it will remain the only way in which the agronomic performance of clones can be assessed for the foreseeable future. Thus, significant on-going activities in this area should continue.

Genetic variation in Foc
To date, considerable progress has been made in characterizing the extent and geographic distribution of genetic variation in this pathogen. However, large and important production areas have not been assessed in Asia, Africa and the Americas. Continued work on the genetic diversity and phylogeny of populations of Poc is needed, especially in the non-explored areas.

(1) This report was prepared as a result of meetings held in Guadeloupe in which the following participants were involved: E. de George (ARC-TSC), K. Pegg (QGQV), A. Pires de Mace (EMBRAAV), R. Ploetz (Univ. of Florida), M. Smith (QGQV), R. Velmans (EMBRAAV). In addition, the following scientists were consulted subsequently to the Guadeloupe meeting: J. Hernandez (CICA) A. Kastner (NARO), N. Moore (QGQV), M. Rivers (FHIA) and M. Rutherford (CAB-IJM).

2. Research Strategy
Early screening tests have been developed but these require strengthening in order to produce significant information on pathogenic diversity in Foc and on resistance in the host. On-going field screening efforts will continue to provide much needed information.
on the resistance of parents and progeny to the important pathotypes of Foc. As breeding (conventional and biotechnology) and the recognition of variants of Foc continues, this effort will need to be expanded. In addition, the results obtained from early screening will have to be verified in the field. Studies on the variation in Foc will continue with further collections being made in important producing areas in Asia, Africa and the Americas. The efficiency of breeding efforts will be increased through the identification of markers which are linked to resistance and efforts will be made to enhance the hardness of tissue culture plantlets.

3. Areas for Collaboration

Informal links established between University of Florida, QBPI and ARC-ITSC and breeding programmes:
- University of Florida with FIHA and IITA;
- ARC-ITSC with FIHA and CIMMYT (in future);
- QBPI with FIHA and CIMMYT;
- Internal link between University of Florida, Homestead and University of Florida, Gainesville;
- Internal link between QBPI and CRCTPP and QBPI and QF;
- External link between ARC-ITSC and TRRI (Jordan);

Need to develop close links with NARS on 01213/01216 areas e.g. MARDI, CRRII, synergies created where mutual benefit.

EMBRAPA/ENMPF with QBPI.

3.1 New areas for collaborative research

**Early screening test - Fundamental to success of PROMUSA**

Requires a 3-way collaboration between a tissue culture laboratory supplying good quality plantlets, the early screening centre, and a field site to verify results.

**Genetic variation**

Inability to collect in some areas due to funding constraints.

**Field screening**

No site for detailed studies with 01213/01216 - sites available in Malaysia and Indonesia but clear mutual benefit must be provided.

**Molecular markers**

Need to identify suitable F₂ segregating populations. Ideally there should be a black and white situation for resistance/susceptibility - also need to study inheritance of resistance.

3.2 Identification of research needs requiring inter-group collaboration

- Molecular Markers - need to collaborate with genetic improvement group.
- Evaluation of diploids and progeny - need to collaborate with genetic improvement group and IMTP.
- Hardness of tissue culture plants - need to collaborate with nematology group.
- For pathogen diversity studies - need to collaborate with IMTP.
<table>
<thead>
<tr>
<th>Organization</th>
<th>Early screening test</th>
<th>Pathogen characterization</th>
<th>Field evaluation</th>
<th>Marker-assisted selection</th>
<th>Plantlet vigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBRRI Taiwan</td>
<td>Interested</td>
<td>No</td>
<td>Large field screening scheme in place. The VCGs at this location are unknown. Subtropical race 4 is present here.</td>
<td>No</td>
<td>Interested</td>
</tr>
<tr>
<td>Taiwan National University</td>
<td>No</td>
<td>VCGs</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>OTA Canary Islands</td>
<td>Interested</td>
<td>VCGs and RAPDs</td>
<td>012D01215 site for IMTP II.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>MARDI Malaysia</td>
<td>No</td>
<td>No</td>
<td>Good site with 0121301216.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CRIB, Boekel Samanta</td>
<td>No</td>
<td>No</td>
<td>Also has 0121301216 site.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>University of Sains Malaysia</td>
<td>No</td>
<td>VCG</td>
<td>In cooperation with Mak Chai (Kuala Lumpur) has conducted experiments in another 0121301216 site.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>University of Bonn Germany</td>
<td>Interested</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Ph.D. student works on endophytes.</td>
</tr>
<tr>
<td>Philippines</td>
<td>Interested</td>
<td>No</td>
<td>0122 here</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>EMBRAPA/CPMF Brazil</td>
<td>Preliminary work being conducted.</td>
<td>No</td>
<td>Major strength Fields infested, VCGs under characterization at ODPI.</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organization</th>
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<th>Field evaluation</th>
<th>Marker-assisted selection</th>
<th>Plantlet vigour</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA Honduras</td>
<td>No</td>
<td>No</td>
<td>Yes to Race 1 and 2.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>UK (CAB international) UK (also networked collaboration with other UK and East Africa-based groups)</td>
<td>No</td>
<td>Extensive experience - mitochondrial FLUPs and probes; PCR methods - RAPD, SSR, rDNA ITS &amp; IGS, introns of other loci; extracellular enzymes; metabolite and enzyme production activity; VCGs Permit held for importing and working with non-indigenous isolates. Comprehensive range of isolates held in internationally recognised Genetic Resources collection.</td>
<td>Undertaken by collaborators in East Africa.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ITA Uganda</td>
<td>No</td>
<td>No</td>
<td>Plans exists for work on putative 01240125 site.</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>ARC-ITSC South Africa</td>
<td>No</td>
<td>No</td>
<td>RAPDs</td>
<td>Major strength with 012081215 fields.</td>
<td>Interested</td>
</tr>
</tbody>
</table>

A list of acronyms and abbreviations is provided at the end of the document.
## Medium-Term Plan

<table>
<thead>
<tr>
<th>Goals</th>
<th>Outputs</th>
<th>Indicators</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance identification of nematode species</td>
<td>Field screening</td>
<td>Identification of nematode species</td>
<td>5 years</td>
</tr>
<tr>
<td>Strengthen nematode management</td>
<td>Nematode control</td>
<td>Percentage of control achieved</td>
<td>10 years</td>
</tr>
<tr>
<td>Increase resource availability</td>
<td>Resource mobilization</td>
<td>Amount of resources mobilized</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>

### Field Screening
- **Objective**: Identifying nematode species in the field.
- **Indicators**:
  - Identification of nematode species
  - Percentage of control achieved
  - Resource mobilization

### Nematode Control
- **Objective**: Controlling nematode populations.
- **Indicators**:
  - Number of controlled species
  - Percentage of population reduction
  - Control strategies employed

### Resource Mobilization
- **Objective**: Mobilizing resources for nematode control.
- **Indicators**:
  - Amount of resources mobilized
  - Cost of mobilization
  - Impact on local communities

### Medium-Term Plan

<table>
<thead>
<tr>
<th>Goals</th>
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</tr>
<tr>
<td>Increase resource availability</td>
<td>Resource mobilization</td>
<td>Amount of resources mobilized</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>

### Nematode Working Group

1. **Scope of Work, Priority Research Needs and Major Constraints**

#### 1.1 Scope of work
The Nematode Working Group is to concentrate on the identification of sources of nematode resistance and tolerance, their underlying mechanisms and the pathogenic variability between and within the major nematode pest species of Maize. These activities will also require an improved knowledge of the species composition of nematode populations in major Maize production areas.

#### 1.2 Priority research needs
Although the following five research needs are ranked, their interdependence precludes their strict prioritization.

##### Screening for resistance
Identification of useable sources of resistance to nematode species, including the further development and refinement of early and rapid screening techniques. This research is needed because there is a shortage of identified sources of transferable resistance and/or tolerance to the major nematode pest species.

##### Relationship studies
Studies on the relationship between Maize genotypes, nematode reproduction, root damage, plant growth and other components of yield losses in Maize. This research is needed because it will facilitate further research into the genetic improvement of a range of Maize genotypes, including those traditionally grown for domestic consumption.

##### Pathogenicity studies
Studies on the variability in pathogenicity between and within different nematode pest species in different geographic regions and different Maize production systems. This research is needed due to the recognised pathogenic variability of *Radopholus similis* and its potential existence in other nematode pest species, as well as to counter the potential development of resistance-breaking nematode pathotypes which has occurred in other crop-nematode associations.

##### Mechanisms of resistance
Studies on the mechanisms and inheritance of resistance to nematode species. This research is needed because basic knowledge on mechanisms

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(1) This report was prepared as a result of meetings held in Gona Plume in which the following participants were involved: D. De Waale (KIL), S. Poppas (CABP), K. Price (CAR-IP), J. Price (CABAD), N. Yancey (NIHAP). In addition, the following scientists were consulted subsequent to the Gona Plume meeting: J. Rijp (CAR-DM), S. Gassen (Univ. of Reading), L. Kasaui (NABIO), J. Pinheiro (RITA), P. Sperger (DTA) and J. Stetten (QGRIB).
of resistance and tolerance will assist breeding programmes in genetic improvement, for example, by the development of molecular markers for use in classical breeding.

**Species profiles**

Studies on the occurrence of the major nematode pest species within different geographic regions and different *Musa* production systems. These activities are needed because the relative importance of the major nematode pest species in the different geographic regions and production systems is poorly understood. In addition and directly related, is a lack of knowledge of the potential interactions between different nematode pest species and their possible influence on any resistance or tolerance identified in *Musa*. This knowledge will be needed to enable the future prioritisation of research needs in the various geographic regions and production systems.

**1.3 Major constraints**

- Lack of awareness of the importance of plant-parasitic nematodes as potential production constraints to *Musa*, largely due to a lack of comprehensive empirically derived data demonstrating yield losses caused by the most important nematode pest species to the major *Musa* genotypes.
- Shortage of personnel trained in *Musa* nematology, especially in national programmes.
- Severe financial constraints contributing to institutional instability of research efforts.
- Shortage of available services for specialised nematode identification to provide back-up to field scientists.

**2. Research Strategy**

- Conduct pot and field experiments for identification of resistant and/or tolerant *Musa* genotypes.
- Identify suitable locations with different species compositions for the conduct of field experiments for the evaluation of relationships between genotypes, nematode reproduction, root damage and other components of yield loss, and the performance of experiments.
- Further collect and identify pathogenic variability in nematode species, particularly species other than *Heterodera schachtii*.
- Perform detailed studies of the nematode population dynamics, morphological, histological and biochemical studies of the genotypes to elucidate the mechanism of resistance once resistant and tolerant genotypes are identified.
- Sample an appropriate number of fields in representative *Musa* production systems and determine the nematode species composition of the area, to help prioritise the major nematode species.

**3. Areas for Collaboration**

**Screening**

FHI, CRISP, KUL, IITA, IITA-BSCNC, EMBRAPA, CIARD, University of Reading, GFPI, IITA/CICA, CAB/UV, SARO. Output could be increased through an exchange of methodology, exchange of data on relative resistance of tissue-culture plants versus conventional plant material, exchange of data on the genotypes that are screened and their reactions. Early screening of promising or scarce genotypes in the screen-house can then be followed up by more extensive field trials. This would improve and enhance the screening processes at the various institutions.

**Pathogenic variability of nematodes**

KUL, IITA Uganda, CAB/UV, CIARD, USDA, GFPI, CRISP, IITA-CICA. Output could be increased by exchange of methodology, results and nematode cultures. Replication or division of research would enhance the validity of research findings.

**Mechanisms of resistance**

CIARD, ORSTOM, University of Reading, IITA-ESARS, CRISP. Output could be increased by avoiding unnecessary duplication of research activities and findings thus generated would be more comprehensive.

**3.1 New areas for collaborative research**

Studies of yield losses caused by nematodes in semi-intensive and small-holder production systems in different agro-ecological regions. Other areas of research that need expansion and collaboration between institutions are the study of mechanisms of resistance and the pathogenic variability. An expansion of screening sites (e.g. in Southeast Asia) will enable the assessment of locally important *Musa* genotypes and will accelerate the production of relevant research findings.

The adoption of common or mutually compatible research methodologies between different research groups should be encouraged. A good example is the recently prepared "Technical Guidelines for the Screening of *Musa* Germplasm for Resistance and Tolerance to Nematodes".

**3.2 Identification of research needs requiring inter-group collaboration**

Studies on the relationships between *Musa* genotypes, nematode reproduction, root damage, plant growth and other components of yield losses in *Musa* will benefit from collaborative activities with both the Pasarurian and Sigatoka working groups. In particular, this may help to establish the significance (or otherwise) of nematode-pathogen interactions. A further aspect which merits consideration is the basis of the apparent multi-pathogen resistance in some genotypes e.g. Yangambi Km 5. This would also require collaboration with the Genetic Improvement Group, for example in the development of a gene-mapping programme and on the determination of the inheritance of resistance.
### 4. Inventory of Existing Facilities, Expertise and On-going Research

#### 4.1 Existing facilities and expertise

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Areas of expertise</th>
<th>Particular characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>QOPI Australia</td>
<td>Field screening, yield loss assessments.</td>
<td>Regional Masa collection.</td>
</tr>
<tr>
<td>KUR Belgium</td>
<td>Glasshouse screening, pathogenicity studies, mechanisms of resistance.</td>
<td>Molecular techniques INIBAP Transit Centre nematode collection (about 15 accessions).</td>
</tr>
<tr>
<td>Univ. of Gent Belgium</td>
<td>Taxonomy.</td>
<td></td>
</tr>
<tr>
<td>EMBRAPA/CNPPEM Brazil</td>
<td>Screening, yield loss assessments, pathogenic diversity of nematodes, ecological studies.</td>
<td>Existing breeding programme, presence of most major nematode spp., agro-ecological diversity, molecular techniques.</td>
</tr>
<tr>
<td>CRBP Cameroon</td>
<td>Field and screen-house screening, mechanisms of resistance.</td>
<td>Agro-ecological diversity, Presence of most major nematode spp. Existing breeding programme.</td>
</tr>
<tr>
<td>University of Dachang Cameroon</td>
<td>Nematode taxonomy.</td>
<td>Classical taxonomy.</td>
</tr>
<tr>
<td>CORPOICA Colombia</td>
<td>Screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>CORBANA Costa Rica</td>
<td>Screening, yield loss assessments, pathogenic diversity of nematodes, ecological studies.</td>
<td></td>
</tr>
<tr>
<td>IDEFOR Citro d'Alvone</td>
<td>Field screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>Various Cuba</td>
<td>Screening, yield loss assessments.</td>
<td>Strong potential but lack of international exposure and linkages.</td>
</tr>
<tr>
<td>INIAP Ecuador</td>
<td>Screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>USDA, Florida USA</td>
<td>Pathogenic diversity of nematodes.</td>
<td>Molecular techniques.</td>
</tr>
<tr>
<td>CIRAD/INRSTOM France</td>
<td>Glasshouse screening, pathogenicity studies, mechanisms of resistance.</td>
<td>Molecular techniques. Nematode culture collection (approx. 50 accessions).</td>
</tr>
<tr>
<td>Univ. of Bonn Germany</td>
<td>Pathogen interactions.</td>
<td></td>
</tr>
<tr>
<td>Univ. of Ghana</td>
<td>Field screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>CRI Ghana</td>
<td>Field screening.</td>
<td></td>
</tr>
<tr>
<td>CIRAD/INRSTOM Guadeloupe</td>
<td>Screening, yield loss assessments.</td>
<td>Existing breeding programmes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Laboratory</th>
<th>Areas of expertise</th>
<th>Particular characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>IFAD Honduras</td>
<td>Screening, yield loss assessments.</td>
<td>Presence of several important nematode spp. Existing breeding programme.</td>
</tr>
<tr>
<td>NRC India</td>
<td>Field screening, yield loss assessments.</td>
<td>Regional Masa collection.</td>
</tr>
<tr>
<td>IRRI Indonesia</td>
<td>Field screening, yield loss assessments.</td>
<td>Extensive regional Masa evaluation.</td>
</tr>
<tr>
<td>Volcani Research Center Israel</td>
<td>Screening, yield loss assessments.</td>
<td>Sub-tropical. Importance of Helicotylenchus multirictus.</td>
</tr>
<tr>
<td>MARDI Malaysia</td>
<td>Field screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>CIRAD/INRSTOM Martinique</td>
<td>Yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>Institut Hassan II Morocco</td>
<td>Yield loss assessments.</td>
<td>Importance of Meloidogyne incognita. Sub-tropical.</td>
</tr>
<tr>
<td>Univ. of Los Bailes Philippines</td>
<td>Field screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>ARC-ITSC South Africa</td>
<td>Field, screen-house screening, yield loss assessments.</td>
<td>Sub-tropical.</td>
</tr>
<tr>
<td>PPRI South Africa</td>
<td>Availability of identification services (classical).</td>
<td></td>
</tr>
<tr>
<td>National Programme Tanzania</td>
<td>Field screening, yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>NRI Thailand</td>
<td>Yield loss assessments.</td>
<td></td>
</tr>
<tr>
<td>NARO Uganda</td>
<td>Field screening, yield loss assessments.</td>
<td>Agro-ecological diversity, presence of most of the important nematode species and H. multirictus.</td>
</tr>
<tr>
<td>Univ. of Reading UK</td>
<td>Glasshouse screening. Pathogenicity, mechanisms of resistance.</td>
<td>Nematode culture collection.</td>
</tr>
</tbody>
</table>
## Medium-Term Plan

<table>
<thead>
<tr>
<th>Goal</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Indicators</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Screening for resistance</strong></td>
<td>Collecting missions or existing germplasm collections. Equipment and expertise.</td>
<td>Sources of useful resistance/tolerance following screening of part of available germplasm collection.</td>
<td>Nematode resistance incorporated into new hybrids.</td>
<td>5 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sources of useful resistance/tolerance following screening of an additional part of the germplasm collection and incorporated in agronomically useful germplasm.</td>
<td></td>
<td>10 years</td>
</tr>
<tr>
<td><strong>Relationship studies</strong></td>
<td>Equipment and expertise. Suitable evaluation sites.</td>
<td>Increased knowledge within the major Muza genotypes, of the relationships between nematode populations and various components of yield loss.</td>
<td></td>
<td>6 years</td>
</tr>
<tr>
<td><strong>Pathogenicity studies</strong></td>
<td>Equipment and expertise. Collections of nematodes from different regions.</td>
<td>Nematode pathotypes will be grouped and ranked based on their pathogenicity.</td>
<td></td>
<td>5 years</td>
</tr>
<tr>
<td><strong>Mechanisms of resistance</strong></td>
<td>Information from basic research activities. Equipment and expertise.</td>
<td>Understanding of mechanisms of resistance/tolerance at the morphological, cellular genetic and molecular level. Molecular markers identified. Resistance genes identified.</td>
<td>Use of molecular markers by breeding programmes.</td>
<td>7 years</td>
</tr>
<tr>
<td><strong>Species profiles</strong></td>
<td>Surveys.</td>
<td>Identification of global and regional significance of the major nematode pest species.</td>
<td>Priority list of major nematode species.</td>
<td>Several short term surveys during a period of 10 years.</td>
</tr>
</tbody>
</table>
Virology Working Group¹

1. Scope of Work, Priority Research Needs and Major Constraints

1.1 Scope of Work

Viruses are recognized as a significant problem leading to constraints in Maize improvement on two grounds: yield losses which can be up to 100% and a constraint to germplasm movement. Four viruses are currently recognized as being significant: banana bunchy top virus (BBTV), banana streak virus (BSV), banana bunch mosaic virus (BBMV), and cucumber mosaic virus (CMV); there are reports of other viruses but these have not yet been characterized. As virtually nothing is known about these other viruses, it is suggested that a watchful brief is kept on them. The main demands are for:
- Detection and diagnostic systems for breeding, tissue culture and germplasm movement (quarantine).
- Resistance to the viruses.

1.2 Priority research needs

**Virus detection and therapy**

In relation to virus detection, there is a need for the development of improved, robust, simple and accessible diagnostic systems.

The importance of the simplicity and robustness would depend upon who was carrying out the diagnosis: international centers, NARS, propagation centers, users (farmers, industry, etc.) BSV presents a unique case as there is a strong probability that the three forms of the virus (encapsidated epizonal, unencapsidated epizonal and integrated) would require different diagnostic techniques. Further research is also needed in the areas of virus variability, geographical distribution of the different viruses, cultivar reaction to virus infection and the molecular biology of the viruses themselves. In addition, research is required on the development of a technique to eliminate viruses from infected plants. Table A lists these four major topics on which virus detection research is needed (+) together with prioritization (1) both for the topic and virus.

The prioritization is based on the perceived importance for an efficient diagnostic system.

**Virus resistance**

There is a lack of resistance in Maize to the major viruses but there is the possibility that resistance is present in related genera and families which could be introgressed into Maize.

(1) This report was prepared at a result of meetings held in Glandenope in which the following participants were involved: G. Bahls (ITTA), J. Dao (BSV), A. Ina (BSV), B. Lounis (U. of Minnesota), S. Sharrock (ISNIP), I. M. E. Carranza (CIAT), B. Lockhart (U. of Minnesota), S. Sharrock (ISNIP). In addition, the following scientists were consulted subsequent to the Glandenope meeting: H. Mole (Glandenope) and J. Thomas (GPP).
last two topics are constraints which would become relevant on field release of transformed plants but for which consideration has to be given at early stages of the project. Selection markers, e.g. use of antibiotic genes, should also be considered at this stage.

1.3 Major constraints
- a lack of known sources of genetic resistance in Musa species.
- the small number of specialists working in this area.
- a need for further attention to be given to biosafety and IP2 considerations.

2. Research Strategy
The goal is the control of viruses in Musa. This will be by transgenic approaches to conferring resistance in Musa and development of diagnostic systems to support this approach and to produce virus-tested germplasm and planting material.

3. Areas for Collaboration

Transformation
Transformation is essential for progress in the development of transgenic resistance and in many cases requires collaboration between scientists working on molecular aspects of the viruses and those with expertise in transformation.

Molecular markers
Collaboration in this area will have some application in use of transgenes for breeding but especially for resolving problems relating to BSV integration. It could also be of use in IP issues.

Virus detection
Collaboration is required in this area in developing diagnostic systems suitable for the end user.

3.1 New areas for collaborative research
International screening of transgenic plants. The field release of transgenic Musa lines will require collaboration between the biotechnologists, biosafety officials, breeders, agronomists and others. Studies have to be made as to how to effect this as efficiently as possible.

Stresses which induce activation of integrated BSV: An understanding of the factors leading to the activation of integrated BSV is of major importance in the application of new technologies to Musa improvement. This will involve collaboration between molecular biologists, tissue culture experts, breeders and transformers.

3.2 Identification of research needs requiring inter-group collaboration
- Transformation with the Genetic Engineering Sub-group of the Genetic Improvement Group.
- Molecular markers with the Breeding and Genetics Sub-group.

4. Inventory of Existing Facilities, Expertise and On-going Research

4.1 Existing facilities and expertise

<table>
<thead>
<tr>
<th></th>
<th>BBrMV</th>
<th>CMV</th>
<th>BRTV</th>
<th>BSV</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Southern China</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CIARAD, France</td>
<td>+</td>
<td>+d</td>
<td>+</td>
<td>+d</td>
<td>+</td>
</tr>
<tr>
<td>Gembloux/KUL, Belgium</td>
<td>+t</td>
<td>+t</td>
<td>+t</td>
<td>+t</td>
<td>+t</td>
</tr>
<tr>
<td>IFAPA, Nigeria</td>
<td>-</td>
<td>+d</td>
<td>-</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>JIC, UK</td>
<td>-</td>
<td></td>
<td>+d</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>HU, Taiwan</td>
<td>-</td>
<td>+d</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>QI, Australia</td>
<td>+</td>
<td>+d</td>
<td>+</td>
<td>+d</td>
<td>+</td>
</tr>
<tr>
<td>QUT, Australia</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+d</td>
<td>+</td>
</tr>
<tr>
<td>UOM, Hawaii USA</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+d</td>
<td>-</td>
</tr>
<tr>
<td>UOM, USA</td>
<td>-</td>
<td>+d</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>EMBRAPA/CNPMP, Brazil</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ Indicates relevant work being done on virus
- Indicates work in development
- Indicates work on variegated tissue culture lines

Most, if not all the work being done in these organisations is complementary and there is no obvious comparative advantage of any laboratory for any virus.

4.2 Inventory of on-going research

<table>
<thead>
<tr>
<th></th>
<th>BBrMV</th>
<th>CMV</th>
<th>BRTV</th>
<th>BSV</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation</td>
<td>+S</td>
<td>+M</td>
<td>+M</td>
<td>+M</td>
<td></td>
</tr>
<tr>
<td>Distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular biology</td>
<td>+S</td>
<td>+M</td>
<td>+M</td>
<td>+S</td>
<td></td>
</tr>
<tr>
<td>Transformation</td>
<td>+S</td>
<td>+M</td>
<td>+M</td>
<td>+L</td>
<td></td>
</tr>
</tbody>
</table>

S = Short term (1-2 years)
M = Medium term (up to 5 years)
L = Long term (more than 5 years)
* = Indicates research going on in that area for that virus
<table>
<thead>
<tr>
<th>Goal</th>
<th>Inputs</th>
<th>Outputs</th>
<th>Indicators</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development and demonstration of efficiency of a cassette for transgenic resistance to BBTV, BMiMV and CMV</td>
<td>Basic research on BBTV, efficient transformation system, Strategies to address IPR considerations.</td>
<td>Mechanisms for transgenic resistance to BBTV, Information on genome variability within CMV isolates infecting Mice, Resistance constructs for each of BMiMV, BBTV and CMV.</td>
<td>Availability of diagnostic systems suitable for use by a wide range of users.</td>
<td>3 years</td>
</tr>
<tr>
<td>Development of robust diagnostic systems for BBTV, BMiMV and CMV</td>
<td>Basic information on BIBTV variation.</td>
<td>Understanding of the molecular basis of latent BBTV strains, Determination of the distribution of latent BBTV strains, Development of diagnostics for the detection of latent BBTV strains.</td>
<td></td>
<td>5 years</td>
</tr>
<tr>
<td>Genetically modified plants protected against viruses</td>
<td>IP and biosafety considerations. Transgenic and conventional approaches.</td>
<td>Varieties transgenically protected against viruses, Field tested and farmer released, Varieties with integrated protection against other pathogens and pests linked with other agronomic characters.</td>
<td>Resistant varieties available to farmers.</td>
<td>10 years</td>
</tr>
<tr>
<td>Obtaining basic information on the BSV-system which can be used for the development of transgenic strategies and detection systems.</td>
<td>Basic research on BSV system information from breeders to indicate which parental lines produce highest proportion of BSV infected plants.</td>
<td>Understanding of the integration(plus) system, Characterisation of active integrated forms, Understanding of factors which activate integrated forms, Development of diagnostics for the detection of integrated forms.</td>
<td></td>
<td>3 years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Characterisation of the status of integrated forms in cultivars of interest (parental lines, tissue culture stocks). Understanding of variation of active integrated and epissomal forms.</td>
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<td>5 years</td>
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Global and Regional Evaluation

1. Introduction

An efficient mechanism for evaluating germplasm is an essential component of PROMUSA. In relation to this, an International Musa Testing Programme (IMTP) has been co-ordinated by INIBAP since 1989. A global IMTP meeting was held in Guadeloupe on March 29th and 30th to evaluate the results of the second phase of the programme and to discuss future proposals for this programme. In view of the increasing number of breeding programmes wishing to contribute hybrids and NARS wishing to evaluate these new hybrids, the participants at the meeting agreed to make some major modifications to IMTP to enable it to better respond to the different needs of programme partners. The new structure of IMTP should allow it to play an important role in the global and regional evaluation of germplasm in the framework of PROMUSA.

2. Scope of the Work

The International Musa Testing Programme (IMTP) is a global initiative in which improved varieties, breeding materials, accessions with possible sources of resistance and standard checks are tested at the global and regional level with the following objectives:

- To obtain pathological information and agronomic evaluation data to feedback to breeding programmes.
- To provide NARS with improved varieties.

3. Strategy

The identification of germplasm with disease resistance/tolerance, with desirable agronomic characteristics and with local adaptation by evaluation in different locations world-wide. The participation of NARS ensures that improved hybrids are made available to them at an early stage and through the creation of linkages, the bi-directional flow of information between breeding programmes and evaluation sites is facilitated.

*(1)* This report was prepared as a result of meetings held in Guadeloupe in which the following participants were involved: F. Bailey (CIRAD), W. Collarte (World Bank), J. Dale (ICRF), J. De Beer (ABU-PNM), R.L. De Looze, B. De Wachter (CIRAD), S.E. Bastiaens (CIP), N. Dahal (IRRI), E. Feuillet (CIRAD), E. Piras (INIBAP), P. Pensaert (World Bank), J. Bernard (CIRAD), T.L. Berry (INIBAP), E. Gombocz-King (CIRAD), C. Jannin (CIRAD), B. C. L. Leitgeb (Univ. Minnesota), D. Meekers (CIRIAD), J. Magee (ISNB), N. Mulika (IRDC), K. Nangia (CIP), S. Naot (IRRI), B. Orya (INIBAP), B. Pong (INIBAP), F. De Mater (CEBRAP/CPMP), G. Pinto (Univ. Florida), B. Roncorio Calderon (COOBRAN), P. Rowe (FITA), A. De Schot (CTA), M. Saito (IPCI), S. Sek predatory (CTA), H.P. Singh (NRC), M. Smith (CIRAD), R. Sweers (CIRAD), R. Tavoma (CTA), R. Trippe (INIBAP), R. Vanmaerck and (CIRAD), K. Tomase (CIP), R. Trippe (INIBAP), P. V. Nui (MAPP), N. Vissacco (FITA) and D. Vorhees (ITTA).
4. Modus Operandi

Promising new material is identified by breeding programmes and sent to the INIBAP Transit Centre (ITC) where it is introduced in vitro, virus indexed, and multiplied. This material is then made available to interested NARS for screening for disease resistance using standard guidelines previously agreed upon by the participants in IMTP.

In the first two phases, all material donated to the IMTP was evaluated at all sites using the same protocol, and this has yielded important information on disease resistance/tolerance. As a result, several improved varieties have been recommended for further distribution and are now being commercially cultivated in a number of countries. However, as the number of improved hybrids becoming available for testing increases, and with an expanding number of national programmes interested in evaluating such improved material, a new more flexible approach for IMTP has been developed (Figure).

Within the new structure of IMTP, two different evaluation protocols will be used to address the two main objectives:

- In-depth evaluation sites
- Performance evaluation sites

Revised structure of IMTP

ITC: INIBAP* Transit Center
MGIS: Maize Germplasm Information System

In-depth evaluation sites

Very detailed studies will be carried out at the in-depth evaluation sites. The evaluations at these sites will include not only disease and pest resistance/tolerance screening but can also be combined with epidemiological studies on pathogen populations, studies on host/pathogen relationships for different races of the pathogen and adaptability and yield studies. The evaluation protocols at these sites are elaborate, requiring time and expertise.

The in-depth evaluation sites will also be used for screening potential breeding parents for resistance to pathogens not present at the breeding sites. The information obtained will be primarily useful to breeders and pathologists.

Performance evaluation sites

At the performance evaluation sites, the collaborators will assess the disease resistance, agronomic adaptation and stability of the improved hybrids under their particular conditions. The evaluation protocols to be used at these sites are simple requiring less time and expertise than those used at the in-depth evaluation sites. Moreover, collaborators at these sites will select the clones they wish to evaluate, based on local needs and conditions. Such a programme has a strong regional focus, with varieties being selected for evaluation according to national/regional needs. The information obtained will be primarily useful to extension agents and farmers.

Both types of sites will provide feedback information on the agronomy, pathology and adaptation of improved varieties tested in the International Maize Testing Programme. This information will be compiled in a database which has been designed for this purpose and which in the future will be linked to the Maize Germplasm Information System (MGIS). The information is then fed back to the breeding programmes and is also available for other NARS to assist in their choice of appropriate well characterised varieties.

5. Activities

- Identification of improved hybrids;
- Introduction in vitro, virus indexing, propagation and dissemination of material;
- Elaboration of the structure of a database;
- Gathering basic agronomic and disease resistance data from breeding programmes;
- Elaboration of the actual database in the framework of MGIS;
- Provision of evaluation training to IMTP site managers;
- Establishment of trials and carrying out evaluations;
- Gathering data from sites and feeding the database;
- Make the database available to collaborators - both breeding programmes and NARS.
Acronyms and Abbreviations

ACO 1-aminoacyclopropane-1-carboxylic acid oxidase
ACS 1-aminoacyclopropane-1-carboxylic acid synthase
APHIS-USDA Animal and Plant Health Inspection Service - United States - Department of Agriculture
ARI Advanced Research Institute
ARC-ITSC Agricultural Research Council, Instituto for Tropical and Subtropical Crops, South Africa
ASPNET Asia and Pacific Regional Network, INIBAP, Philippines
BADC Belgian Administration for Development Co-operation
BBMV banana bunch mosaic virus
BTTV banana bunch top virus
BIP Banana Improvement Project
BLSD black leaf streak disease
BPI Bureau of Plant Industry, Philippines
BSV banana streak virus
BTI Boyce Thompson Institute, USA
CABI CAB International, UK
CATIE Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica
CFC Common Fund for Commodities, the Netherlands
CGIAR Consultative Group on International Agricultural Research
CICY Centro de Investigaciones Científicas de Yucatán, Mexico
CIRAD Centre de coopération internationale en recherche agronomique pour le développement, France
CITA Centro de Investigación y Tecnología Agraria, Canary Islands
CMV cucumber mosaic virus
CNPMF Centro Nacional de Pesquisa de Mandioca e Fruticultura, EMBRAPA, Brazil
CORBANA Corporación Bananera Nacional, Costa Rica
CORPOICA Corporación Colombiana de Investigación Agropecuaria, Colombia
CRBP Centre de Recherches Régionales sur Bananiers et Plantains, Cameroon
CRCTTP Cooperative Research Centre for Tropical Plant Pathology, Australia
CRI Crop Research Institute, Ghana
CRIR Central Research Institute for Horticulture, Indonesia
DNA deoxyribonucleic acid
EMBRAPA Empresa Brasileira de Pesquisa Agropecuária, Brazil
ESARR East and Southern Africa Regional Centre, IITA, Uganda
FAO Food and Agriculture Organization of the United Nations
FHEA Fundación Hondureña de Investigación Agrícola, Honduras
FLHOR Département des productions fruitières et horticoles, CIRAD, France
Fusarium oxysporum f. sp. cubense
HKUST Hong Kong University of Science and Technology
HRI Horticulture Research Institute, Thailand
IACR Integrated Approach to Crop Research, UK
IARC International Agricultural Research Centre
ICIA Instituto Canario de Investigaciones Agrarias, Spain
IDEFOR Institut des Forêts, Côte d’Ivoire
IDRC International Development Research Centre, Canada
IEB Institute of Experimental Botany, Czech Republic
IFAD International Fund for Agricultural Development, Italy
IGS intergenic spacer of the ribosomal DNA gene
IIP International Institute of Parasitology, UK
IITA International Institute of Tropical Agriculture, Nigeria
IMI International Mycological Institute, UK
IMTP International Mycological Institute, UK
INIBAP Instituto Nacional de Investigaciones Agropecuarias, Ecuador
INIBAP International Network for the Improvement of Banana and Plantain, France
IP intellectual property
IPGRI International Plant Genetic Resources Institute, Italy
IRTA Instituto de Recerca i Tecnologia Agroalimentaries, Spain
ITC INIBAP Transit Centre, Belgium
ITS internal transcribed spacer of ribosomal RNA gene
JIC John Innes Centre, UK
KARI Kavli Royal Institute of Science, India
KAU Kerala Agriculture University, India
KUL Katholieke Universiteit Leuven, Belgium
MAF Ministry of Agriculture and Forestry, Tonga
MARDI Malaysian Agricultural Research and Development Institute, Malaysia
MGS Musa Genome Information System
NARO National Agricultural Research Organization, Uganda
NARS National Agricultural Research System
NRRC National Research Centre on Banana, India
NRI Natural Resources Institute, UK
NUT National University of Taiwan
ORSTOM Institut français de recherche scientifique pour le développement en coopération, France
PCR polymerase chain reaction
PRRI Plant Protection Research Institute, South Africa
QDPI Queensland Department of Primary Industries, Australia
QTL quantitative trait loci
QUT Queensland University of Technology, Australia
RAPD random amplified polymorphic DNA
tDNA ribosomal DNA
RFLP restriction fragment length polymorphism
RIIF Research Institute of Fruits, Indonesia
SD Sida disease
SB Taiwan Banana Research Institute
UF University of Florida, USA
UNDP United Nations Development Programme
UOH University of Hawaii, USA
UOM University of Minnesota, USA
USDA-ARS United States Department of Agriculture-Agricultural Research Service
VASI Vietnam Agricultural Science Institute
VCG vegetative compatibility group
VIC Virus Indexing Centre
WIBDOECO Windward Islands Banana Development and Exporting Company
YS yellow Sigatoka
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