Advancing banana and plantain R&D in Asia and the Pacific - Vol. 13

Proceedings of the 3rd BAPNET Steering Committee meeting held in Guangzhou, China
23-26 November 2004

A.B. Molina, L.B. Xu, V.N. Roa, I. Van den Bergh and K.H. Borromeo, editors
The mission of the International Network for the Improvement of Banana and Plantain (INIBAP) is to sustainably increase the productivity of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

The programme has four specific objectives:

· To organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved banana cultivars and at the conservation and use of *Musa* diversity.

· To promote and strengthen collaboration and partnerships in banana-related activities at the national, regional and global levels.

· To strengthen the ability of NARS to conduct research and development activities on bananas and plantains.

· To coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

INIBAP is a network of the International Plant Genetic Resources Institute (IPGRI), a Future Harvest center.

The International Plant Genetic Resources Institute (IPGRI) is an independent international scientific organization that seeks to advance the conservation and use of plant genetic diversity for the well-being of present and future generations. It is one of the 16 Future Harvest Centres supported by the Consultative Group on International Agricultural Research (CGIAR), an association of public and private members who support efforts to mobilize cutting-edge science to reduce hunger and poverty, improve human nutrition and health, and protect the environment. IPGRI has its headquarters in Maccarese, near Rome, Italy, with offices in more than 20 other countries worldwide. The Institute operates through three programmes: (1) the Plant Genetic Resources Programme, (2) the CGIAR Genetic Resources Support Programme and (3) the International Network for the Improvement of Banana and Plantain (INIBAP).

The international status of IPGRI is conferred under an Establishment Agreement which, by January 2003, had been signed and ratified by the Governments of Algeria, Australia, Belgium, Benin, Bolivia, Brazil, Burkina Faso, Cameroon, Chile, China, Congo, Costa Rica, Côte d’Ivoire, Cyprus, Czech Republic, Denmark, Ecuador, Egypt, Greece, Guinea, Hungary, India, Indonesia, Iran, Israel, Italy, Jordan, Kenya, Malaysia, Mauritania, Morocco, Norway, Pakistan, Panama, Peru, Poland, Portugal, Romania, Russia, Senegal, Slovakia, Sudan, Switzerland, Syria, Tunisia, Turkey, Uganda and Ukraine.

Financial support for IPGRI’s research is provided by more than 150 donors, including governments, private foundations and international organizations. For details of donors and research activities please see IPGRI’s Annual Reports, which are available in printed form on request from ipgri-publications@cgiar.org or from IPGRI’s Web site (www.ipgri.cgiar.org).

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Cover: A banana field in Yunnan province (photo by Xu Linbing).


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Acknowledgments

The Banana Asia Pacific Network (BAPNET) is grateful to all participants of the 3rd BAPNET Steering Committee meeting for their contribution to these proceedings.

BAPNET would like to thank:

- Its local partners in China, the Guangdong Academy of Agricultural Sciences (GDAAS) and the Science and Technology Department of Guangdong Province, for hosting the meeting and having provided the staff support and local arrangements that ensured the meeting’s success under the able leadership of Mr Xu Linbing, Senior Agronomist, Pomology Research Institute, GDAAS;
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- V.N. Roa and K.H. Borromeo who undertook the style editing, layout and design of the proceedings.

Editorial Note

Some references have been submitted without complete publishing data. They may thus lack the full names of journals and/or the place of publication and the publisher. Should readers have difficulty in identifying particular references, staff at INIBAP-Asia Pacific will be glad to assist.
## Contents

### Workshop recommendations

### Opening ceremonies

- Opening remarks
  - Luo Fuhe

- Strengthening research to improve the banana industry
  - Ma Xian Min

- Message from INIBAP
  - Agustin B. Molina, Jr.

### Country reports

- Australian banana industry: Status and R&D update
  - Robert Williams

- Status of banana in Bangladesh
  - Md. Abdus Sattar and Md. Abdul Hoque

- Overview of banana research in Cambodia
  - Men Sarom

- Banana research and production in China
  - Xu Linbing, Yang Hu, Huang Bingzhi and Wei Yuerong

- Banana and plantain R&D in India
  - M.M. Mustaffa and S. Sathiamoorthy

- Banana R&D in Indonesia: Updates and highlights
  - Suyamto, I. Djanika and A. Sutanto

- Enhancing Malaysian banana industry R&D
  - Nik Masdek Hassan

- Current situation of banana R&D in Myanmar
  - Aye Tun

- Highlights of banana R&D in Papua New Guinea
  - Rosa Kambouou

- Philippine banana R&D highlights 2004
  - Patricio S. Faylon, Jocelyn E. Eusebio and Edna Anit

- Banana R&D in Sri Lanka: Status and prospects
  - Chandrasiri Kudagamage

- Comparison of *Musa* germplasm in Thailand
  - S. Chandraparnik, C. Dichiavong and K. Bansiddhi

- Current banana R&D in Vietnam
  - Ho Huu Nhi

- Status of banana R&D in the Pacific
  - Mary Taylor

- Recent R&D of banana in Taiwan
  - Chi Hon Chen and Chih Ping Chao
Special presentations

Screening of banana clones for resistance to fusarium wilt in China
   Chen Houbin, Xu Chinxiang, Feng Qirui, Hu Guibing,
   Li Jianguo, Wang Zehuai and Agustin Molina, Jr. 165
Population structure of wild banana, Musa balbisiana, in China
determined by SSR fingerprinting and cpDNA PCR-RFLP
   X.J. Ge, M.H. Lui, W.K. Wang, B.A. Schaal and T.Y. Chiang 175
Establishment of embryogenic cell suspension culture
and plant regeneration of banana (Musa spp.) for gene transformation
   Xue-Lin Huang, Yue-Rong Wei, Xian Huang,
   Jia Li, Wang Xiao and Xiao-Ju Li 177
Preliminary evaluation of IMTP-III varieties and local cultivars
against fusarium wilt disease in southern China
   Huang Bingzhi, Xu Linbing and Agustin B. Molina, Jr. 187
Status of banana R&D in Hainan, China
   Chen Yeyuan, Wei Shouxing and Zhang Lei 193

INIBAP/IPGRI programmes

INIBAP programmes and conservation use of banana diversity
   Agustin B. Molina, Jr., Jean-Vincent Escalant
   and Inge Van den Bergh 205
The IMTP, NRMDCs and EPMG: Instruments to enhance
the maintenance, multiplication and promotion of Musa varieties
in Asia and the Pacific
   Inge Van den Bergh, Maria Angeli G. Maghuyop,
   Jean-Vincent Escalant and Agustin B. Molina, Jr. 211
Safe exchange of Musa germplasm, knowledge of the genome
and its application in Musa improvement
   Ines van den Houwe, Nicolas Roux, Jean-Vincent Escalant
   and Richard Markham 217
Promoting conservation through sustainable use of
underutilized crops in livelihood development -
A case of buckwheat
   Zongwen Zhang 231

Appendices

Appendix 1: Programme of the 3rd BAPNET Steering
   Committee meeting 243
Appendix 2: Directory of BAPNET SC members/hosts/
   resource persons/guests/secretariat 245
Appendix 3: Awards 251
Appendix 3: List of acronyms and abbreviations 255
3rd Banana Asia Pacific Network Steering Committee Meeting

第三届亚洲太平洋香蕉网络指导委员会会议 2004.11.23·广州
Workshop recommendations
Workshop recommendations

After the presentations, a workshop was held to review and discuss the status of the various projects in the region, the direction and the future plans of BAPNET. These were the recommendations formed by the committee members:

1. **R&D in the area of IPM with emphasis on banana fusarium wilt, banana viruses and bacterial wilt**
   The observed infection of fusarium wilt on Cavendish in China, Taiwan, Indonesia, Malaysia, Philippines and Australia, and the absence or limited information about Foc from other countries such as Cambodia, Myanmar, Sri Lanka and other BAPNET member countries, necessitate a new survey-characterization of the Foc pathogen in the region. A map distribution of the various races and VCGs of Foc has to be developed. The Regional Coordinator (RC) together with Bob Williams of Australia will explore some possibilities of funding support for the activity from the Australian government.

2. **Review the status and need of a banana breeding programme in Asia**
   Although Asia and the Pacific is the centre of *Musa* diversity, there is no serious and sustainable breeding programme in the region. While some hybridization and mutation induction and selection is carried out in some countries, the major activity carried out in the region is local variety evaluation and selection. It was suggested that the network/NARS link and learn from outputs from a few strong breeding programmes from other countries. A regional initiative to establish a breeding programme should be considered. A serious effort to source national/regional funding and collaborative efforts should be sought if a sustainable breeding programme is to be achieved.

   Existing breeding strategies and related activities of the various member countries of BAPNET are shown in Table 1.

   It can be observed from the above table that all countries practise germplasm evaluation. Other activities, such as molecular characterization, somaclonal evaluation and selection, chemical induction mutation, irradiation mutation, hybridization and genetic transformation, are not yet very popular for most countries in the region. It was agreed that the countries should learn from other breeding programs in order to come up with their own breeding programme strategies.
3. **Enhance banana information sharing**

INIBAP/BAPNET has strengthened efforts on *Musa* information sharing, especially in the areas of Integrated Pest Management (IPM), germplasm characterization and evaluation, and value-adding processes. Research activities such as in the area of biological control are carried out in the region. Sharing and consolidating of results and experiences hastens technology development and utilization.

To enhance information development and exchange, RISBAP should be supported, particularly in the gathering and sharing of banana R&D technical information and publications in the region to be shared into the global INFODOC databases. There is a need to reconstitute the national RISBAP representatives.

4. **Support capacity building on specific thematic areas**

Table 2 shows the needs of the various countries on specific areas and the capacity of some to provide the expertise. The members will see how things can be facilitated to help one another in the region. Some countries which are more experienced than other countries offered to facilitate a training programme in the area of their expertise. An additional training on IMTP guidelines for those who joined later is also recommended. Furthermore, Papua New Guinea specifically made a request for training on MGIS. A MGIS training was held in December 2003 in Malaysia in which PNG was not able to participate.

### Table 1. Existing breeding strategies and related activities of the various member countries of BAPNET.

<table>
<thead>
<tr>
<th>Country</th>
<th>Germplasm evaluation</th>
<th>Molecular characterization</th>
<th>Somaclonal evaluation</th>
<th>Chemical Induction mutation</th>
<th>Irradiation mutation</th>
<th>Hybridization</th>
<th>Genetic transformation</th>
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</table>
5. **Strengthen national activities on promotion, evaluation and adoption of introduced improved varieties and superior landraces, IPM and improved production systems**

Efforts to secure funding for these activities should be sourced from local funding and possibly bilateral funding. Such activities should include more demoplots, training of technicians and farmers on improved IPM and production technologies, and expanded variety evaluation trials.

6. **Other recommendations**
   - Explore/consider the contribution of biotechnology in the area of pest and disease diagnostics.
   - Consider commodity-chain approach in the network programmes.
   - Participate in the proposed banana enterprise-uses studies and workshops.
   - Publish fact sheets of each BAPNET member country. This covers status of banana R&D and collaborative activities within the framework of INIBAP/BAPNET.
   - Review and improve the role of BAPNET in the areas of:
     - Enhancing regional collaboration;
     - Facilitation of knowledge, technology and information sharing;
     - Capacity building;
     - Resource generation; and
     - Priority agenda setting.

### Table 2. Needs and capacities of various BAPNET-member countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>MGIS</th>
<th>Molecular markers</th>
<th>Virus indexing</th>
<th>Antibody production</th>
<th>Diagnostic tools</th>
<th>Foc, sigatoka</th>
<th>Field management</th>
<th>Tissue-culture</th>
<th>MTP methods</th>
<th>Participatory Research</th>
<th>Quarantine issues</th>
<th>Post-harvest, packaging, SCM</th>
<th>Downstream processing</th>
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<td>INIBAP</td>
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</tbody>
</table>

**o**: identified need  **x**: can provide/facilitate
Plotting of national networks

The following are the key activities of the networks of each country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Existing network</th>
<th>Need for a network</th>
<th>What are the key activities of these networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>x</td>
<td>x</td>
<td>Develops the National Strategic RD&amp;E plan (lead by industry); determines the investment plan in collaboration with the R&amp;D providers; and assist in lobbying for funding.</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>x</td>
<td></td>
<td>Identifies the research areas; and technology transfer.</td>
</tr>
<tr>
<td>Cambodia</td>
<td>x</td>
<td></td>
<td>Identifies the research areas; technology transfer and marketing constraints; provides linkage to farmers.</td>
</tr>
<tr>
<td>China</td>
<td>x</td>
<td>x</td>
<td>Sharing of information and exchange; research agenda setting; strategic planning.</td>
</tr>
<tr>
<td>India</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indonesia</td>
<td>x</td>
<td>Fusarium</td>
<td>Sharing of information and exchange; research agenda setting; strategic planning.</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Informal</td>
<td>Keep informal</td>
<td>Provides platform for project development.</td>
</tr>
<tr>
<td>Myanmar</td>
<td>x</td>
<td>x</td>
<td>Identifies the research areas; technology transfer, helps secure government funding; knowledge sharing.</td>
</tr>
<tr>
<td>PNG</td>
<td>PGR</td>
<td>Sub committee</td>
<td>GRNC, with NARI; acts as a sub committee to provide information generation and dissemination to farmers; ability to generate funding within the country from DEC/CBD.</td>
</tr>
<tr>
<td>Philippines</td>
<td>x</td>
<td>x</td>
<td>Team leader; develops national strategic and operational programmes that provides direction for the R&amp;D institutions and the funding agencies.</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>Starting</td>
<td>x</td>
<td>Coordination &amp; information sharing; project development.</td>
</tr>
<tr>
<td>Thailand</td>
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</tr>
<tr>
<td>Taiwan</td>
<td>x</td>
<td>x</td>
<td>Initiation of R&amp;D linkage to farmers</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Starting</td>
<td>x</td>
<td>Research working group; sharing of information and germplasm material exchange; research agenda setting; strategic planning; capacity building; and project development</td>
</tr>
<tr>
<td>SPC</td>
<td>Regional PGR</td>
<td>Regional PGR</td>
<td>Coordination body of PGR players; strategic planning</td>
</tr>
</tbody>
</table>
Opening ceremonies
Opening remarks

Luo Fuhe

Distinguished BAPNET members, ladies and gentlemen, a pleasant good morning to all and welcome to China.

On behalf of the BAPNET Steering Committee meeting, the National Agricultural Research Systems (NARS) and the Guangdong Academy of Agricultural Sciences (GDAAS), I would like to extend my warmest welcome to all the BAPNET members and the participants from different NARS and institutions. The whole GDAAS family is greatly honoured to host this very significant regional event, to be one with BAPNET in advancing our vision to make banana and plantain R&D benefit the region and to share the many exciting developments in banana research.

Banana is an important fruit in China. The volume of production last year was 5.6 million tonnes, and it is estimated that production will reach over 6 million tonnes this year. China has the biggest potential market, with 1.3 billion in population. In 2002, China exported 40 000 tonnes. The export sum was US$19 million. However, we imported 348 000 tonnes of banana from the Philippines and Thailand, costing about US$75 million. Due to the rapid economic growth, the banana consumption market expanded. Chinese Prime Minister Wen Jiabao announced in the Association of Southeast Asian Nations (ASEAN) Meeting in Bali, Indonesia last October that China will establish friendly relations with ASEAN countries to develop economy for mutual benefits, and build the region into a secure and harmonized place with ASEAN countries. Hence, we are glad and proud to make the significant contribution to BAPNET.

GDAAS is one of the leading banana R&D institutions in China. Our work on banana started in the mid 1950s. Over the decades, we were involved in banana germplasm collection, screening, fusarium wilt resistance breeding and tissue culture where significant developments have been achieved. In 1999, we have received a 3rd Grade National Science and Technology Progress Award, and in 2001, the China Excellence Patent Award. We have set up the Guangdong Banana Sciences and Technology Association in 2000. This coming 6 December 2004, we will launch the China Banana Network, which is envisioned to be very helpful to the Chinese banana industry. We are pleased to share the achievement, technology and the market with the countries

*Vice Chairman, Guangdong Provincial Political Consultant Committee, and President, Guangdong Academy of Agricultural Sciences, China.*
in the region.
Lastly, I would like to take this opportunity to wish the meeting a success with fruitful discussions and deliberations that will benefit both the Chinese banana industry and the banana production in the region. I hope you all have a wonderful and unforgettable time in China during this 4-day meeting. Again, welcome to China.
Strengthen research to improve the banana industry

Ma Xian Min

Honourable Chairman Luo Fu He, distinguished BAPNET members, ladies and gentlemen,

I take pleasure in welcoming all of you to the 3rd BAPNET Steering Committee Meeting.

I likewise extend my sincere appreciation to the Guangdong Provincial Science and Technology Department for co-hosting this meeting, and to INIBAP and BAPNET for organizing this important event.

Guangdong is located in the south of China, facing South China Sea with the Tropic of Cancer going through the middle of the province, Hongkong and Macao. It has a 178 000 km² land area with a population of about 80 million people. Guangdong has a sub-tropical climate, with long summers and warmer winters, and a flush of precipitation.

Guangdong is an important harbour. The world-famous “sea silk road” starts from Guangdong. Guangdong has one of the fast developing economy among the provinces in China. In 2003, Guangdong registered a share of 1/9 of the GDP, 1/7 of the financial income, 1/4 of foreign investments and 1/3 of exports of China. Pearl River Delta is one of the biggest IT manufacturing bases in the world.

Science and technology are very important in Guangdong’s development. The policies of Guangdong uphold the practice of research and education. After 20 years of promotion, Guangdong has become the third in science and technology research after Beijing and Shanghai. The big Pearl River Delta (including Hongkong and Macao) has become the most powerful innovation district. Now, the provincial government has enacted a policy on building up science and technology to make the province more powerful.

According to Deng Xiaoping, “Science and Technology are important for productivity. There are 1.05 million researchers in Guangdong. The total research fund is $4 billion, with about $200 000 allotted to banana research every year. Although it is not a big fund, the achievements have been numerous: the use of tissue culture seedlings, the establishment of a germplasm collection, the introduction and screening of new cultivars and research and development in new technologies.”

*Vice Director, Science and Technology Department of Guangdong Province, China.
Many research awards have been received, all of which are considered as a great contribution to the Chinese banana industry.

Guangdong is the hometown of Chinese banana, especially in Gaozhou and Dongguang city, where banana planting has been on for more than 600 years. There are 30,000 ha planted to banana in the two cities. It is said that they are the masters of the Chinese banana industry. Many Guangdong farmers grow banana in other provinces, extending the technology to the other farmers. Also, many researchers extend the new technology and varieties to other regions, thereby stirring a development in the banana sector. During the past 20 years, banana production has increased 10 times. This is the contribution Guangdong farmers, researchers, professors and businessman. They made the banana more profitable for the farmers.

As will be evidenced by the new buildings in the banana-growing regions when you visit the banana plantation on Nov. 26, you can conclude that the farmers earn more money than civilians. This implies that the banana industry is becoming prosperous.

At this point, allow me to extend my appreciation to all of you for your active commitment and dedication to the vision of BAPNET. I hope this meeting will be fruitful and productive, for the benefit of the millions of banana farmers in the Asia and the Pacific region.

Again, I welcome you to Guangdong, with high hopes for the success of this meeting.
Message from INIBAP

Agustin B. Molina, Jr.

Good morning ladies and gentlemen.
This 3rd BAPNET meeting would be a good venue to have a closer look at the future, and plan what else we could do to improve the banana R&D in the region.

But before I dwell into that, allow me to do my routine round of greetings to all of you. Looking around, I can see old and new faces in this meeting. This year, we have 5 new members in the committee, all carrying with them a lot of hope, expectations and zeal to participate and contribute significantly to the activities and realization of objectives of BAPNET. I would like to welcome Dr Satter from Bangladesh, Dr Chandraparnik from Thailand, Dr Aye Tun from Myanmar, Mr Chen from the Taiwan Banana Research Institute and Dr. Suyamto from Indonesia. I am sure that they will bring in new ideas and vigour to the network.

To date, we could say that BAPNET has achieved modest but relevant accomplishments. As the platform of collaboration for the Asia and the Pacific region, BAPNET adds value to the individual efforts of each country in developing banana R&D. In Asia, we all have common problems and opportunities. By working together, exchanging ideas, helping one another, putting our efforts together in synergy, we can advance banana R&D especially for small-scale farmers more rapidly than if we work individually. This is basically the whole value of the network. I had an opportunity of looking at the networks of INIBAP and I am proud to say that I personally believe that BAPNET is the most active among all four networks.

At this point, I would like not only to congratulate China for being a good host but to also comment on their banana industry. This meeting presents a good opportunity to China as banana is becoming very important in the country. As the Chinese economy expands, I would imagine that more money is available to buy bananas, hence the demand for bananas in China would be tremendously high, with more than 1 billion Chinese potential banana consumers. A similar trend is also observed by looking at the export and production data in the Philippines. I can see that there is an increase in production of bananas in the Philippines and an expansion of areas devoted to bananas. And they are looking at China now for that is where the market is. But of

*Regional Coordinator for Asia and the Pacific, Los Baños, Laguna, Philippines.*
course China is thinking of itself also. For that, we could say that there are a lot of opportunities and challenges in China. I hope we can discuss these opportunities and challenges as it affects other countries as well.

We could also learn from the experiences of other countries. More specifically, I am talking about fusarium wilt of banana. It is a major disease of many local cultivars in our region. The threat is more real as a virulent form, fusarium race 4, that can attack the variety Cavendish which is important in China, Taiwan, Australia, and the Philippines. This race has already been reported in Malaysia, Indonesia, Taiwan, and in the Northern Territory, Australia. In Indonesia and Malaysia, race 4 is the major constraint in the establishment of Cavendish in commercial plantation scale. Now this disease is also spreading in China and causing an alarm among Chinese researchers. I think they are now putting a lot of effort towards this. This disease is also a problem in Taiwan, but with technology, they were able to manage it successfully.

I believe that the activities of BAPNET and also of INIBAP, from the global perspective of basic research will be very beneficial. If we put all our efforts together, I think we can solve this many banana production constraints such as fusarium wilt. I could not express my gladness now that after talking with our Chinese partners, Dr Luo Fuhe mentioned that there is going to be a China banana network. This network will improve the synergy and collaboration of all scientists and stakeholders working on bananas in China. INIBAP and BAPNET will be honoured to participate in this network.

As Dr Roux mentioned, INIBAP is a programme of IPGRI. Recently, there was a strategic improvement of direction of IPGRI. They realized that conservation cannot be achieved just for the sake of conservation. The genetic resources that we have must be used. Otherwise, there is no point in conserving them. We are not only thinking of the future generation. We are also thinking of the present generation. Conservation through use is the name of the game, and that is the strategy. For that reason, IPGRI has looked at the INIBAP and COGENT as model programmes. As such, we now have a new strategy wherein the 3 commodities, banana, coconut and cacao, are combined into one commodity programme that emphasizes on the germplasm development and use for livelihoods. These are the new challenges that we have at IPGRI and I am glad that the banana programme was used as a model for the development of livelihood.

INIBAP works with partners. Through partners, we develop the technologies and identify their needs and whatever limited resources we have. We work along that line. And I hope that in this meeting, we
will continue to identify priorities, and at the same time look at our weaknesses and strengths and make plans accordingly. I look forward to a productive meeting in the next 4 days.

In behalf of our director, Dr Richard Markham, I would like to thank all of you for your active participation, and with special thanks to our Chinese hosts for their hospitality and for the successful hosting of this important meeting.

Thank you very much.
Country reports
Australian banana industry: Status and R&D update

Robert Williams*

General production issues
Banana production in Australia over the past three years has been through a period of very difficult times. In north Queensland, the major production area for Cavendish, recovered from the outbreak of black sigatoka in 2001 through to 2003. Survey results have now indicated the eradication programme that was implemented has been successful, however throughout this period banana price have been very depressed resulting in many medium and small growers exiting the industry. The larger companies have taken up this loss on production by planting more.

In Northern Territory, no further outbreaks of fusarium race 4 have been detected, and the disease has not spread to any other production areas.

Drought conditions, increasing land prices and lack of productivity compared to north Queensland have seen a significant reduction in banana production in these areas. Lady Finger production has now shifted to the cooler areas of north Queensland.

Australian banana production has remained static at just over 22 million cartons (297 000 tonnes) for approximately 14 000 ha. Consumption has continued to increase to just over 15 kg/head/year.

The majority of production is AAA Cavendish types (Williams, Mons Mari and Grande Naine) grown in tropical areas north of the Tropic of Capricorn, whilst AAB Pome – Lady Finger are grown in southern or higher altitude regions in north Queensland. The Eco banana has captured a small but developing market as more growers move into this production and marketing system. Small quantities of ABB Ducasse (Pisang Awak) and AAAB Goldfinger are providing a demand in other niche markets.

The major cultivars are

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavendish</td>
<td>90%</td>
</tr>
<tr>
<td>Lady Finger</td>
<td>8%</td>
</tr>
<tr>
<td>Goldfinger</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
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</tbody>
</table>

*Science Leader - Horticulture and Forestry Science, Department of Primary Industry and Fisheries, South Johnstone, Queensland, Australia.
Restraints on the industry

The Australian banana industry was once a very organized group of producers, having a peak industry body and regional representation, that provided the industry with a solid strategic direction, political representation, funding for R&D and quarantine regulations. However, this has fallen apart in the last two years. Although the peak industry body (Australian Banana Growers Association) still remains, and has primary responsibility for the management of import risk assessments, regional operations are dysfunctional. This has resulted in loss of strategic research priorities and funding and the potential collapse of the internal banana quarantine protocols that have protected the Australian industry from many of the international pests and diseases. The loss of R&D funding has resulted in no new research projects for the past two years.

While the industry structure is collapsing, additional external factors are imposing significant demands on the production of bananas in Australia such as:

- Labour costs
- Workplace health and safety
- Environmental impact from farming

The lessons learnt from what has happened in Australia provides BAPNET with an opportunity to evaluate how programmes are delivered and adopted by small growers in developing countries. By providing community groups with training in how to assess what the key issues are that impact on their business, and then work with them to address these priorities, greater adoption will result. This is the opposite to what is happening at the moment, where researchers are telling farmers what their problem are and giving them the results of their research.

Research programmes

Outcomes and progress in the research and development projects have been significant. Abstracts of many of the projects are attached in Annex 1.

The R&D programme is focusing along in 4 major themes:

**Competitive production systems**

- IPM. Developing a systems approach to pest and disease control.
- Decision support. Production and management systems that maximize efficiency.
• Irrigation/nutritional management to maximize inputs but minimize environmental impacts.
• Diagnostic tools for pest and disease detection.
• Mechanization of production and packaging systems.

Environmental sustainability
• Soil health. Developing monitoring tools as indicators of environmental impact.
• Environmental Management Systems (EMS). Combining the various productions and management.

Product innovation
• Varietal evaluation.
• Marker technology.
• Food solutions.

Supply chain solutions
• Postharvest handling.
• QA systems.

Banana research agencies in Australia
- Queensland Horticulture and Forestry Science.
- Queensland Agricultural Biotechnology Centre (QDPI/UQ).
- Queensland University (UQ).
- Queensland University of Technology (QUT).
- Cooperative Research Centre for Tropical Plant Protection (CRCTPP).
- New South Wales Department of Agriculture.
- Western Australia Department of Agriculture.
- Northern Territory Department of Agriculture and Fisheries.
Note: A new CRC for National Plant Biosecurity is being proposed.

Peak industry body
Australian Banana Growers Council. (ABGC).
Australian Banana Congress to be held in Cairns in August 2005

Collaboration prospects
Australia has over many years collaborated extensively with many Asian Pacific countries in a wide range of research projects. This collaboration
has resulted in Australia having extensive strong team in:
- fusarium
- virus of banana
- nematodes
- *Erwinia*
- *Mycosphaerella* leaf diseases
- integrated pest management
- banana tissue culture
- banana characterization
- banana genome
- biotechnology
- cropping system management
- information systems

Research agencies within Australia are keen to join in collaboration with neighbouring countries in research projects which align with priority areas for all agencies.

**Key issues for INIBAP/BAPNET**
- Publication of Brazil Fusarium Symposium.
- Publication of papers from the Malaysian Congress.
PROJECT TITLE: Chemical and non-chemical control of banana corm rot
PROJECT NUMBER: FR03025
PROJECT START: January 2004
PROJECT COMPLETION: January 2007
PROJECT/PROGRAM LEADER: Steve Akiew
Tel: (07) 40484600; Fax: (07) 40923593; Email: steve.akiew@dpi.qld.gov.au
PROJECT TEAM: Steve Akiew (Bacteriologist), Lynton Vawdrey (Plant Pathologist), Stewart Lindsay (Extension Officer), Kim Badcock (Experimentalist), Victoria Jones (Molecular Biologist)

SYNOPSIS OF PROJECT: A new type of banana corm rot, not previously recorded in Australia, was identified in 1997 on several plantations in Tully-Innisfail, with infections ranging from 2% to 12%, and appears to be increasing in incidence. Corm rot severely affects mature plants, particularly the first ratoons during the summer season. It is soil-borne, and enters the plant through wounds caused by insects, machinery, tools and chemical injury. Plants may tip over quite easily, being broken across the rotted rhizome. The disease also occurs in the Northern Territory and Western Australia. Banana corm rot in Australia is caused by the bacterium *Pectobacterium (Erwinia) chrysanthemi*.

These research project commenced in January 2004 to further study *P. chrysanthemi* in-depth, develop a molecular diagnostic tool (polymerase chain reaction, PCR) to identify the bacterium, and devise control methods that could be used in conjunction with the agronomic practices recommended for commercial banana production in Queensland.

PROGRESS TO DATE: A polymerase chain reaction (PCR) protocol for the identification of *E. chrysanthemi* in bananas has been developed and has been successfully used to identify the pathogen. Genetic variations have been observed amongst *P.chrysanthemi* strains isolated from bananas in Queensland and in Western Australia. Pathogenicity of the bacterium has been successfully established, and field trials have commenced to confirm the effectiveness and applicability of chemical and non-chemical options to reduce the impact of the disease on yield of Cavendish. Bacteria that are highly antagonistic to the corm rot bacterium and chemicals registered for agricultural use are being tested in for field application. A corm rot management protocol will be made available to banana growers and researchers by 2007.

CRITICAL ISSUES IMPACTING ON THE PROJECT: The most critical issue impacting on the project is the seasonal variations from year to year that appear influence the occurrence and severity of the disease. This directly affects experimental results obtained within a limited (1-2 years) period. Sufficient funding to support a five-year project would have a positive impact on this type of project.

LINKAGES TO OTHER PROJECTS: Soil Health Project (Tony Pattison), Biofumigation Project (ACIAR).
PROJECT TITLE: Management options for banana bunch pests

PROJECT NUMBER: FR00013

PROJECT START: Dec 2000

PROJECT COMPLETION: March 2004

PROJECT LEADER: David Astridge

PROGRAM LEADER: Bob Williams

Tel: (07) 40641160; Fax: (07) 40642249; Email: david.astridge@dpi.qld.gov.au

PROJECT TEAM: David Astridge, Jeff Lambert, Tanya Martin and Stewart Lindsay

SYNOPSIS OF PROJECT: The major bunch pests in Australia include the banana scab moth (*Nacoleia octasema* (Meyrick) (Lepidoptera: Pyralidae) and banana rust thrips (*Chaetanaphothrips signipennis* (Bagnell) (Thysanoptera: Thripidae)) which are responsible for up to 90% of all bunch damage. Banana flower thrips (*Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae)) and sugarcane bud moth (*Opogona glycyphaga* Meyrick) (Lepidoptera: Tineidae) are also becoming increasingly important pests to control. Banana bunch pests can cause serious fruit damage resulting in market rejection and the loss of grower income. The current commercial control of banana bunch pests is primarily based on the strategic use of organophosphate insecticides, which can be harmful to the environment and human health. Investigations are currently under way by the Australian Pesticides & Veterinary Medicines Authority (APVMA) to identify, restrict or eliminate the use of environmentally toxic pesticides. The APVMA is currently reviewing chlorpyrifos, one of the most heavily relied upon insecticides. This has increased the priority of the Australian banana industry to find alternative insecticides for bunch pest management. Reduced dependence on organophosphate insecticides is essential to promote sustainable pest management practices and further develop integrated pest management (IPM) in the Australian banana industry. This project investigated the efficacy and potential for using environmentally soft insecticides. Biopesticides, and other insecticides with new modes of action were tested as alternatives to organophosphates for the control of banana bunch pests.

PROGRESS TO DATE: Bioassays and field trials have been completed (2000-2003) to examine treatment efficacy against banana bunch pests in Queensland. The most effective new insecticide treatments for banana scab moth control included emamectin benzoate (Proclaim®), tebufenozide (Mimic®), and indoxacarb (Avatar®). All treatments were equally as effective as the chlorpyrifos (Lorsban 750 WG®) standard and gave less than 5% bunch damage in field trials. Thiamethoxam was the only new insecticide treatment that was equally as effective as chlorpyrifos for controlling the pest spectrum.

The pseudo biopesticide spinosad (Success®) was the most effective treatment against all bunch pests and is now registered as a bunch treatment for the control of banana rust thrips and sugarcane bud moth. The fungal biopesticides *Beauveria bassiana* and *Metarhizium anisopliae* although producing slower
mortality times in the lab bioassays then the new insecticide treatments and spinosad were not significantly different (P<0.05) in the level of fruit damage compared to the other treatments. Although reasonable control was achieved against all bunch pests the high levels of phytotoxicity present in the field trials make these treatments unacceptable at this time. Future research will concentrate on changing the oil formulations to reduce the phytotoxic effects in the developing bunches and testing different dose rates.

The potassium based fatty acids treatment (Natrasoap®) had reduced efficacy against banana rust thrips making this treatment unacceptable at the reduced rate tested (5ml/L). Bacillus thuringiensis var. kurstaki gave very good control of banana scab moth and sugarcane bud moth in field trials and were equally as effective as the chlorpyrifos standard.

In the insecticide impregnated plastics trial the diazinon and suSCon® strips as well as the chlorpyrifos impregnated bunch covers were equally as effective as dusting and spraying with chlorpyrifos and achieved less than 5% bunch damage against all pests. The low toxicology profiles, unique modes of action and good efficacy of all treatments make them suitable for use in developing insecticide resistance management strategies, further developing IPM in Australian bananas.

**FUTURE WORK AND RECOMMENDATIONS:** It is recommended that,
(1) insecticide efficacy; dose rate and residue data is generated to proceed with product registration of all treatments equally as effective as the chlorpyrifos standard. (2) Additional insecticides with new modes of action and low mammalian toxicity are registered so an effective insecticide resistance management strategy can be developed. (3) The potential for using biological insecticides should be further investigated by testing new pathogens against the pest complex in bananas. (5) Field trials are repeated for southeast Queensland to examine environmental effects on treatment biodegradation.

**CRITICAL ISSUES IMPACTING ON THE PROJECT:** None

**LINKAGES TO OTHER PROJECTS:** Management of Banana Rust Thrips (HAL Project No FR96023)

**POSSIBLE FUTURE INIBAP (ACIAR) PROJECT:** “Taxonomy and Potential Biological Control of Banana Scab Moth (Nacoleia octasema (Meyrick) (Lepidoptera: Pyralidae) in Australasia"

**AIM:** To further develop IPM systems in bananas by identifying and introducing potential biological control agents for the control banana scab moth.

**WORK REQUIRED:** Detailed taxonomy of the banana scab moth throughout its geographic regions (eg. Malaysia, Indonesia, Fiji, Vanuatu, New Guinea) as well as all species of its food plants is required to further enhance the potential for using biological control. Parallel studies are also required on the taxonomy and host preference of the natural enemies to help identify the most suitable biological control agent of this pest. Host preference studies are also required for the
introduction of biological control agents. Once identified predator complexes can be built using ecological engineering methods to establish insectaries suitable for the maintenance and establishment of the biological control agents.

**POTENTIAL OUTCOME:** There is a very good chance that if this work is completed effective biological control agents can be identified and used to help control banana scab moth across the geographic regions for these banana industries. This should result in reducing insecticide applications and enhancing IPM systems for controlling this pest.

**PROJECT TITLE:** Plant tissue culture: providing strategic support for the banana industry

**PROJECT NUMBER** BA04007

**PROJECT START:** November 2004

**PROJECT COMPLETION:** November 2007

**PROJECT/PROGRAM LEADER:** Sharon Hamill - Senior Research Scientist

Tel: 07 54449639; Fax: 07 54412235; Email: Sharon.Hamill@dpi.qld.gov.au

**PROJECT TEAM:** Jeff Daniells - Principal Horticulturist, John Thomas - Principal Plant Virologist, Mike Smith - Principal Research Scientist, Ralf Dietzgen - Principal Biotechnologist,

**SYNOPSIS OF PROJECT:** The Australian banana industry has relied on plant tissue culture in a strategic way for many years and has identified a suite of key activities that can only be achieved by utilising banana tissue culture.

This project provides Australia with a tissue culture quarantine importation laboratory to facilitate safe access to valuable new varieties that are used in research (eg. disease resistance, reduced environmental impacts, improved farm practice and market expansion/diversification). This significant Australian banana germplasm collection of approximately 500 accessions will be maintained in vitro and supported by a field collection that also allows collection of agronomic data on new varieties. Australian researchers need to have access to the Australian collection to look for valuable traits such as pest and disease resistance, improved productivity, including more efficient nutrient use for lower environment impacts for less cost.

One of the aims of this project is to undertake research that will lead to improved quality of tissue cultured plants in reduced susceptibility to pests and diseases and lower incidence of somaclonal variation. Banana tissue culture research in this project will also investigate obstacles to the quality of plants produced including role of endophytic bacteria.

The activities in this project will:
- allow industry to safely import valuable banana varieties.
- maintain Australia’s banana biodiversity as a disease-free collection of plants.
- improve the level of international biosecurity – in combination with virology research.
- supply disease-resistant varieties as part of the disease exclusion or
eradication strategy.

- provide disease-free banana varieties for research and industry evaluation.
- improve Australian domestic quarantine. Australia has the best disease-
  free planting material scheme in the world based on accredited commercial tissue
  culture laboratories and nurseries (QBAN) using tissue culture to produce
  virus-free plants.
- undertake research to understand obstacles to tissue culture quality that
  will eventually assist commercial and research laboratories and subsequently
  encourage uptake of banana tissue culture.

**PROGRESS TO DATE:** The establishment of one of the world’s major *in-vitro*
collections of *Musa* germplasm and, concomitantly, the introduction, multiplication
and distribution of new banana varieties for Australian researchers and producers.

- Registration as the Australian Quarantine Inspection Service tissue culture
  laboratory to facilitate safe importation of banana into Australia
- The establishment of a Quality Banana Approved Nursery (QBAN) Scheme,
  via a network of commercial tissue culture laboratories and nurseries, whereby
  growers can have access to clean, uniform planting material with improved
  productivity.
- The development of ways to eliminate or manage two major problems in
  commercial banana tissue culture. Due to research on virus transmission
  growers can be assured the material they purchase is free from disease.
  While we do not understand the causes of off-types during tissue culture
  production our research has provided selection criteria that allows dwarf
  offtypes to be identified and “rogued” out at the nursery stage. This quality
  selection protocol has reduced the number of off-types reaching the grower.
- Field evaluation of tissue-cultured plants that have identified susceptibility to
  fusarium wilt
- The use of embryo culture and meristem culture.
- The development of autotetraploid varieties using colchicine applied to *in-vitro*
cultures.
- Isolation and identification of endogenous bacteria residing in banana corm
  tissue.

**CRITICAL ISSUES IMPACTING ON THE PROJECT:** The key aim is utilizing
plant tissue culture biotechnology to facilitate biosecurity, promote biodiversity
and create market development opportunities with new varieties.

Increasing pressure from outside the industry, such as threat of imports, disease
incursions, and unreliable markets, plus internal pressures resulting in lack of
industry unity may either encourage growers to take up the challenge of best
practice or cause them to delay. However, there is unanimous agreement that
industry in the meantime will need to maintain its arsenal of strategic research
activities to provide the national industry with the means to move forward.

Likewise, grower uncertainty due to black sigatoka and fusarium incursions
combined with threat of imports have impacted negatively on QBAN where growers
have been delaying plantings until they are more aware of the outcomes of these threats. The developing QBAN tissue culture sector is still struggling with delayed orders and payments resulting in reduced cash flow. Ongoing support will need to be provided.

**LINKAGES TO OTHER PROJECTS:** This project supports all Australian banana research projects that require banana germplasm, both providing material and facilitating importation of new varieties. With its bacteria research component it links to projects looking at biological control agents to improve both plant and soil health.

**Eradication of black sigatoka from Australian banana areas**

Ron Peterson*, Kathy Grice* and Roger Goebel**
Department of Primary Industries and Fisheries, Mareeba* and South Johnstone **.
*PO Box 1054, Mareeba Qld 4088, Australia.

**ABSTRACT:** Black Sigatoka caused by *Mycosphaerella fijiensis* Morelet, was detected in the major banana production area of North Queensland, Australia in 2001. An intense inoculum annihilation program and an intense spray program were conducted over a 6-month period from September 2001 to February 2002, to eradicate the disease. Prevalence of yellow Sigatoka (*M. musicola* Leach), a related disease was reduced from a 96% incidence in the banana areas to extremely low/undetectable levels in more than 96% of the commercial banana areas. All unmanaged banana plants were located and destroyed. In a verification program from May 2002 to May 2003 when the control program was less intense, yellow Sigatoka re-developed in 72% of the area. Yellow Sigatoka also developed on 51% of the unsprayed sentinel plant blocks established throughout the area. Black Sigatoka was not detected during the verification program or during the following 16 months under a less intense surveillance program. To date (November 2004) black Sigatoka has not been detected for 36 months indicating that black Sigatoka was successfully eradicated from the banana production region of north Queensland.

**Key words:** banana; *Mycosphaerella fijiensis*, black leaf streak; black Sigatoka; eradication.

Submitted to INFOMUSA for publication November 2004.

**PROJECT TITLE:** Soil and root health for eco-banana production

**PROJECT NUMBER:** FR02025

**PROJECT START:** 1 July 2002

**PROJECT COMPLETION:** 30 June 2005

**FUNDING SOURCE:** QFVG/HAL/QHI
**PROJECT/PROGRAM LEADER:** Mr Tony Pattison, QDPI
Tel: (07) 4064 1127; Fax: (07) 4064 2249; Email:pattist@dpi.qld.gov.au

**SUMMARY:** This project aims to develop tools for banana growers to determine the health of their soil, by providing practical and usable key soil indicators. The indicators will be developed from a range of soil biological, physical and chemical characteristics. These key soil indicators will be used to validate the improvement in soil health by the use of pre-plant organic amendments and the use of interrow crops. They will also be used to benchmark the current status of soil health on banana farms and also to form a soil health scorecard for use by banana growers that can be incorporated into a management system that allows for continuous improvement in soil health.

A detailed survey will be used to develop the key soil health indicators. Only the most practical and meaningful indicators will be used by banana growers, but will be correlated to measurements of soil processes such as the recycling of nutrients and disease suppression. The survey to develop the key soil indicators will be conducted on similar soil types from the main banana production areas. In each production area, triplicate soil samples will be taken down the soil profile to determine the effects farm management has on soil biological, physical and chemical properties. The samples will be taken from a conventional banana growing soil, a low input or organic banana production system and an undisturbed system, either rainforest or pasture. This will measure the effects of farm management on soil properties and determine which soil characteristics are most susceptible to change due to farm management. The soil characteristics, which are most sensitive to change due to farmer’s management and the most practical for the banana industry to use, will be adopted as key soil indicators throughout the project.

The key soil indicators developed from the initial survey will be used to develop a soil health scorecard for use by banana growers. The soil health scorecard will be tested for practicality and reliability to indicate soil health by a second survey over three years. The survey will take place yearly on banana farms on a range of soil types and management practices. This will indicate the current soil health status of banana soils and what soil characteristics need to be improved. It will also allow banana growers to incorporate a soil health recording system into an environmental management system to validate their method of farming to environmental agencies and allow continuous improvement in soil health.

To help banana growers determine what is the best method to improve the health of their soil, trials are planned to test pre-plant organic amendments and the use of interrow crops. The pre-plant amendments applied to bananas are intended to provide growers with workable solutions to improve the soil health indicators and allow a more sustainable method of soil management. Pre-plant amendments and the soil health indicators will be linked to the sustainability of banana production by measuring plant growth and yields over a three year period. The amendments will also be tested for their addition of nutrients and ability to suppress soil borne diseases. The use of pre-plant amendments builds on
information gathered from previous projects on the use of compost and mill ash to develop disease suppressive soils.

The use of crops in the interrow of bananas is intended to improve the plant, soil and water relationships within the banana paddock and to reduce the movement of sediment from the banana paddock. A number of shade tolerant species will be tested for their ability to persist within the banana interrow, withstand traffic, their resistance to soil borne diseases and their agronomic suitability for a banana production system. The effects of interrow species will also be tested for their effects on the key soil health indicators to determine if this allows growers to improve their soil health and the sustainability of banana growing. The use of interrow crops builds on information gathered on the resistance of banana fallow crops to soil borne diseases.

The project to develop soil indicators to determine the health of banana growing soil has evolved due to the observations made of poor plant growth, restricted root growth and plant toppling observed on banana farms when there is no plant pathogen involved. Often the only apparent cause of poor plant growth is poor soil structure. The poor soil structure has been difficult to describe to banana growers. The effect soil structural degradation has on banana growth has no quantifiable or descriptive measures to indicate to banana growers how poor soil health is impacting on plant growth. To increase the awareness to banana growers of the effects of poor soil structure and soil degradation have on production and sustainability of banana cultivation, pot trials have been included in the project. The pot trials will also investigate the interaction of a pathogen, such as nematodes and Fusarium wilt, on bananas in poorly structured soil. This trial will demonstrate if soil conditions can increase the susceptibility soil borne disease has on banana growth.

The project aims to develop practical science for banana growers to develop useful and practical indicators of soil health. To help with the adoption and uptake of the use of soil indicators, an extension component of the project comprising a biannual newsletter, annual farmer field schools and the development of a banana root and soil health manual and testing kit will be developed. The soil health manual and testing kit will complement one another and allow growers to use a soil health scorecard to assess and validate their management practices in relation to soil health. This information can then be incorporated into an environmental management system for growers to continually improve the health of soils under banana cultivation.

For banana growers to improve their knowledge of soil health practices, they need indicators that can quantify and describe their current soil health status as well as management options that growers can implement to improve soil health. This project will improve the knowledge of soil health, allow growers to monitor and validate soil health and give options to improve soil health management. As a result of improved soil health from this project banana growers will be able to reduce losses due to poor soil structure, validate their farming practices and continuously improve soil health management to sustainably produce bananas in Queensland.
SUMMARY OF PROGRESS:

SURVEY: 34 fields in north Queensland were sampled to validate 4 key soil health indicators: pH, electrical conductivity (EC), NO₃-N and labile C. Samples taken from the fields were processed using soil health kit methods at laboratories in South Johnstone and sub-samples from each field sent to NRM&E accredited laboratories at Indooroopilly for duplicate analysis. The four key soil indicators were significantly related validating the methods used in the soil health kit were able to provide reliable measures of soil properties (Table 1).

Table 1. Correlation of four key soil health indicators between soil health kit measurements and accredited laboratory techniques.

<table>
<thead>
<tr>
<th>Key soil indicator</th>
<th>Equation</th>
<th>Variance accounted for (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>pHₛᵢ = (1.1 x pHᵢ) - 0.7</td>
<td>98 (P&lt;0.001)</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>ECₛᵢ = 0.01 + (0.39 x ECᵢ)</td>
<td>64 (P&lt;0.001)</td>
</tr>
<tr>
<td>NO₃-N</td>
<td>NO₃⁻⁻ᴺₛᵢ = 25.8 + (2.69 x NO₃⁻⁻ᴺᵢ)</td>
<td>71 (P&lt;0.001)</td>
</tr>
<tr>
<td>Labile C</td>
<td>Labile Cₛᵢ = 203 + (155 x Labile Cᵢ)</td>
<td>37 (P&lt;0.001)</td>
</tr>
</tbody>
</table>

ᵢ = measured at Indooroopilly at accredited laboratories.

Labile C measurements had the largest variation between measurements conducted in South Johnstone and Indooroopilly. This may be due to the heterogeneity of carbon in the soil as well as differences in techniques. However, the soil health kit technique of measuring labile C is the only method that can currently be conducted without sophisticated equipment and provides a good indication of the carbon status of the soil.

INTERROW CROPS: Interrow crops, pinto peanut, butterfly pea, carpet grass and bahia grass were planted in January, 2004. Dry matter samples were measured in April, 2004 and revealed pinto peanut and pinto peanut and carpet grass mix had significantly higher dry matter production than other treatments. There were significant differences in soil physical, chemical and biological properties between the interrow and the row area of bananas. Physically, the interrow area had significantly higher bulk density, slower water infiltration and less stable aggregates relative to row area. Chemically, the pH, EC and NO₃-N were significantly lower in the interrow relative to the row. Biologically, the interrow area was a more fungal dominated system, whereas the row area around bananas was bacterially dominated with more plant parasitic nematodes. No nematode suppression has been detected.

PRE-PLANT AMENDMENTS: The pre-plant amendment field trial investigating mill ash, mill mud, compost and grass hay was established on August 28, 2003. Following the application of amendments there was an increase in the soil NO₃-N and soil respiration measurements in compost treated plots resulting in an increase in the bacterial feeding nematodes and increased the bacterial dominance of the soil microbial community. However, at the second assessment in March 2004, there were no differences in soil NO₃-N levels. There was a significant increase in the labile C under the grass hay treatment relative to the untreated plots. This resulted in a reduction in the bacterial to fungal ratio relative to the untreated plots, which suggested that nutrients were being decomposed by a
more fungal dominated pathway. There has been no change in measurable physical properties, plant growth parameters or nematode suppression under the amendments so far in the trial.

The use of silicon amendments has been able to give a significant reduction in fusarium wilt symptoms in glasshouse trials. It is thought that the soluble silicon is able to improve the disease resistance in banana plants. However, the exact method, quantity and best method of application are still being determined.

BENEFICIAL MICROORGANISMS: Beneficial microbe field trial to establish antagonistic organisms to burrowing nematodes has been completed and the results are still being analysed. Initial results suggested there is no nematode suppression or growth promotion in the field from inoculation of plants with beneficial microorganisms. Conversely, an isolate of Cytophaga sp. has given significant suppression of fusarium wilt in pot trials. This is thought to be due to up regulation of endochitinase and osmotin plant defence genes in presence of bacteria and fusarium and direct antagonism of the bacteria against fusarium.

PROJECT TITLE: PCR primer verification and analysis of the black sigatoka outbreak in Tully

PROJECT NUMBER: FR99009

FUNDING SOURCE: BIPB/HAL/CRC Tropical Plant Protection

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TECHNICAL SUMMARY: Black sigatoka, caused by the fungal pathogen *Mycosphaerella fijiensis*, is a major quarantine threat to the Australian banana industry. The disease is endemic in most banana growing regions in the world, including the Torres Strait Islands. Consequently, vigilance is required to prevent introductions to the Australian mainland and for this regular surveillance for leaf spot symptoms is carried out in Queensland banana plantations and diagnosis of suspect lesions is confirmed at the Centre for Tropical Agriculture in Mareeba. Differential diagnosis of black sigatoka is complicated by the occurrence of yellow sigatoka, caused by the closely related species *Mycosphaerella musicola*, which is endemic in Australian banana crops. However, these two pathogens can be reliably distinguished based on morphology of conidial structures if present.

In April 2001, an outbreak of black sigatoka occurred in the Tully Valley. Previous
outbreaks of the disease had occurred on non-commercial properties in North Queensland and each of these had been successfully eradicated. However, the Tully incursion was located in Australia’s largest commercial growing region as well as being in Australia’s highest rainfall zone. In addition, traditional diagnostic methods could not be used as high rainfall had washed away fungal structures necessary for a definitive diagnosis. The Centre for Tropical Plant Protection developed a gel-based PCR assay capable of differentiating black and yellow sigatoka in leaf samples which was used to help diagnose samples during the eradication, surveillance and area freedom programs in the Tully Valley.

Through the combined efforts of scientists, extension officers and banana growers, black sigatoka was declared eradicated from the Tully Valley in May 2003, with no disease detected since November 2001. Following this success, two important questions were highlighted: (1) What was the likely source of the Tully outbreak and (2) would the gel-based assay be capable of detecting future incursions of the disease in Australia?

To address the issue of the likely source of the outbreak, a comprehensive sequence study was undertaken. The internal transcribed spacer (ITS) and intergenic spacer (IGS) and D1/D2 regions of the ribosomal gene complex of *M. fijiensis* were sequenced from banana samples collected during the Tully eradication campaign and compared to an extensive catalogue of isolates of *M. fijiensis* and *M. musicola* as well to *M. eumusae*, a third closely related pathogen which causes a similar disease on banana, Eumusae leaf spot (ELS). Isolates for comparison were sourced from local and international collections and included sequences from Africa, India, Central and South America, the Caribbean, Asia and the Pacific Islands as well as sequences from previous Australian incursions. The results of the phylogenetic analysis revealed a number of important findings: (1) confirmation of *M. fijiensis, M. musicola* and *M. eumusae* as three distinct species; (2) identification of two new species of *M. musicola* occurring in Malaysia and Indonesia and (3) that the source of the Tully 2001 incursion was very unlikely to have been sourced from previous incursions in Cape York but was more likely a new introduction.

To ensure the ability to detect future incursions of black sigatoka and related species into Australia, the ITS sequence data was assessed for integrity of the diagnostic primer sites. In addition, the gel-based PCR assay was screened against the DNA catalogue of local and international isolates of banana and non-banana *Mycosphaerella* spp. as well as other banana phytopathogens. Detection of very low level (0.04%) cross-specificity was found during testing necessitating a more specific assay format to be sought. Consequently, TaqMan® MGB probe assays have been developed for black and yellow sigatoka and these assays are ready for technology transfer.

The conclusion that the source of the Tully 2001 outbreak was most likely from a new introduction and not from a previous outbreak in Cape York, indicates that the earlier eradication programs have been successful. This finding should serve to strengthen confidence in the Tully eradication program and also provide support that eradication should be pursued in the event of any future incursions. The finding that *M. musicola* appears to be comprised of at least three species has
important implications in quarantine. The two possible new species from Indonesia and Malaysia have not been identified in Australia and the pathogenicity of them is unknown. There is a very real possibility that these species could enter Australia undetected and for this reason, it is recommended that an extensive study of *M. musicola* is undertaken to determine if there are differences in pathogenicity in genotypes from different geographical regions.

As a result of this study, improved diagnostic assays for black and yellow sigatoka have been developed. Incorporation of quality assurance controls into this test is desirable and multiplexing the two tests into a single tube assay would have benefits in quality control and cost. The development of a TaqMan® MGB probe assay for *M. eumusae* has begun, however, thorough validation of this assay is necessary. Further work addressing these issues is recommended towards the goal of providing the Australian banana industry with the very best diagnostic tools for surveillance of these exotic pathogens.

**PROJECT TITLE:** Using nutrient-rich bananas to improve health and livelihoods in the Pacific

**ACIAR RESEARCH PROGRAM AREA:** Crop Protection

**PARTNER COUNTRY/IES:** Solomon Islands, Kiribati, Papua New Guinea

**PROPOSED COMMISSIONED IARC:** International Plant Genetic Resources Institute (IPGRI): International Network for the Improvement of Banana and Plantain (INIBAP) programme; Proposed Australian Collaborating Organisations: Queensland Department of Primary Industries and Fisheries (QDPIF); University of Queensland (UQ)

**PROPOSED PARTNER COUNTRY COLLABORATING ORGANISATION/S:** The Secretariat of the Pacific Community (SPC), Fiji; Planting Materials Network, Solomon Islands; National Agricultural Research Institute, Papua New Guinea

**PROJECT SUMMARY:** Vitamin A deficiency is a major cause of debilitating health problems in developing countries and contributes significantly to infant and maternal mortality. Recent studies have shown that some traditional varieties of banana grown in the Pacific islands contain enough provitamin A carotenoids to readily satisfy needs for Vitamin A when consumed in amounts that are realistic in areas (especially Oceania and East/Central Africa) where people (some 400 million, worldwide) eat bananas as a staple food. In particular, Englberger et al. working in the Federated States of Micronesia (FMS) have laid the foundation of this project by demonstrating the basic feasibility of this concept. This project will lead the way for the development of an international effort to encourage wider consumption of carotenoid-rich bananas, based on an assessment of their nutrient content, bioavailability, consumer-acceptability and agronomic-adaptability. Drawing on the expertise of the project collaborators in nutrient analysis (UQ, QDPIF), consumer acceptance (UQ, INIBAP and local partners) and the evaluation and dissemination of banana varieties (QDPIF, SPC, INIBAP and local partners), the results of the project will indicate whether a wider effort based on consumer education and dissemination of existing high-carotenoid varieties is likely to achieve
the desired health impacts or whether it is necessary to invest in breeding efforts to transfer the desired traits to new varieties with wider acceptability and adaptability.

OBJECTIVES WILL BE TO:

- evaluate the carotenoid levels in existing varieties (based on collections of Pacific varieties at QDPIF and elsewhere) and the likely bioavailability of Vitamin A based on the ways in which these bananas are grown, processed and consumed
- identify ethnobotanical uses of banana and gain an understanding of the acceptability of various high-carotenoid banana varieties to consumers, both at first encounter and after nutrition education
- evaluate the agronomic adaptability of promising high-carotenoid banana varieties, considering growth cycle, yield, disease-resistance and adaptation to different agro-ecologies

THE EXPECTED OUTPUTS WILL INCLUDE:

- an understanding of the technical and social factors influencing and limiting the availability of Vitamin A resulting from consumption of high-carotenoid bananas
- initiation of positive health outcomes in the study areas, resulting from increased awareness of the value of consuming high-carotenoid bananas
- the foundation for a realistic inter-regional strategy for using bananas to alleviate Vitamin A deficiency problems in developing countries (which is expected, when implemented through other projects, to have an immediate impact in those Pacific nations where Vitamin A deficiency has been identified, such as the Solomon Islands and Kiribati, and eventually in other regions, especially sub-Saharan Africa).

HOW THE PROJECT WILL BE UNDERTAKEN: The project focuses on novel research on the bioavailability of Vitamin A based on consumption of Musa and will examine pre- and post-harvest factors influencing its availability in both in-vitro and in-vivo studies. Equally important are the social actions and interactions within target countries with technical back-up provided by Australian partners, SPC and INIBAP. Promising banana/plantain cultivars will be identified in existing collections (QDPIF, SPC, NARI, INIBAP Transit Centre) and fruit assessed for carotenoid content and bioavailability. Agronomic assessment of a subset of varieties will begin immediately in Australia and target countries, in order to complete a full production cycle at contrasting sites (rainfall, altitude, soil fertility, disease pressure) within the project period. Participatory methods will be used to evaluate likely acceptability and consumption patterns, with and without complementary nutrition education. For each of the countries, the aim will be to identify the most favorable combination of Vitamin A/bioavailability and social acceptability. Analysis of data within a sociological and biophysical framework (using GIS) will provide a basis for assessing the likely cost and impact of a larger-scale strategy based on disseminating existing high-carotenoid varieties, accompanied by participatory training in food processing, health and nutrition.
Uptake pathways would include future projects of INIBAP regional networks (in both Asia/Pacific and Africa) and SPC.

Australian and International Project partners (other than Pacific NARS):

- Dr Mike Smith, Sharon Hamill, Greg Mitchell, Dr Craig Davis, Jeff Daniells, QDPIF. Germplasm acquisition and characterisation and supply of fruit for analysis; Initiation, virus indexing and provision of banana germplasm; Nutrient analysis, food processing
- Prof Mike Gidley, A/Prof Geoff Marks, Dr Terry Coyne, Dr Faroukh Ahmed, UQ. In vitro bioavailability studies, clinical nutrition and in vivo bioavailability.
- Dr Gus Molina, Dr Richard Markham. IPGRI-INIBAP. Networking for dissemination of materials, information and assessment of cost-benefits for a global program
- Dr Lois Englberger, SPH UQ and Micronesia (contracted through INIBAP). Engagement with local communities to identify promising germplasm, and approaches to assess and enhance the cultural acceptability of nutrient-dense cultivars.
- Dr Mary Taylor, SPC. Sourcing and maintaining banana germplasm, distribution of promising lines and facilitation of evaluation in member countries.
Status of banana in Bangladesh

Md. Abdus Satter* and Md. Abdul Hoque

Banana is the number one fruit in Bangladesh considering its year round availability, popularity and production. It accounts for 41% of the total fruit production from 21% share in area. The average yield of banana is 15 t/ha, which is lower compared with that of other countries in the world. Plantain has a great demand in the urban areas during the lean period of vegetables from May to October.

Banana is a rich source of calories. It is eaten fresh or sometimes mixed with rice and milk, which is the traditional dish for Bangladeshis. It also is used in fish curry, in preparing cakes and other delicious foods. The green peel is also eaten and has a medicinal value.

Malnutrition is widespread in the country. The average food intake is deficient in calories, vitamins and minerals. Bananas can improve the nutritional situation of the country.

Consumption and trade

Most of the bananas produced in the country are consumed in the domestic market. A small quantity is exported to the Middle-East countries. From the farm, banana passes through three middlemen before it reaches the consumer. As a result, farmers are deprived of their actual price.

Cultivars

Table banana

There are a number of banana cultivars in Bangladesh. Among them, BARI Kola-1, ‘Amritsagar’, ‘Sabri’, ‘Champa’ and ‘Kabri’ are the commercial cultivars. The other cultivars are ‘Mehersagar’, ‘Dudsagar’, ‘Agniswar’, ‘Genasundari’, ‘Kanaibanshi’, ‘Basrai’, ‘Binisuta’, etc. The Horticulture Research Centre has 19 cultivars/landraces of table banana in its collection. There are also different types of seeded cultivars growing in the homesteads, roadsides and forests all over the country. These are tall plants, hardy and drought tolerant, which takes a long time to harvest. Most of these cultivars produce sweet fruits which are used as baby food, dessert and in cake preparation. Its inflorescence is eaten as delicious vegetable.

*Director General, BARI, Joydebpur, Gazipur, Bangladesh.
Plantain

Nine distinct genotypes of plantain were identified from 28 collections from different parts of the country. Field evaluation of these selected genotypes was done along with FHIA-03. In this trial, FHIA-03 was found superior to all with respect to yield and disease tolerance. The local genotypes were found susceptible to fusarium wilt. Considering yield potential and disease tolerance, FHIA-03 was released for cultivation as plantain.

Production systems

Banana production in Bangladesh can be categorized into three systems: backyard, mixed and commercial smallholder production. Backyard production of banana is common where the growers produce banana primarily for home consumption. In this system, crop management is very poor, but productivity and longevity is high. Bananas are grown perennially in homestead areas. Practically no fertilizer or pesticides are applied. In a mixed-crop production system, banana is intercropped with potato, onion, mustard, radish, spinach, amaranth, bitter gourd, cabbage, etc. to obtain additional income. In some commercial smallholder plantations, banana is grown as a monocrop. But most of the growers are not well aware of the modern production practices.

Major constraints of banana production

There are several factors contributing to the low production of banana in Bangladesh.

Lack of high-yielding varieties

The existing varieties that are susceptible to diseases are not high yielding.

Pests and diseases

The major pests of banana are banana leaf and fruit scarring beetle, banana weevil and nematodes. Thrips, aphids, stem borer and mites are minor pests. The fruits affected by scarring beetle have poor market acceptability. Table bananas are highly susceptible to this pest. Banana weevil is also causing damage to the corms and pseudostems, resulting in stunted growth, weak plant base, yellowing of leaves and rotting of the corm. Further research is needed to confirm this. Nematodes are a problem in some localities. Farmers are not fully aware of nematodes but they know that one kind of small earthworm damages the roots of
banana. No work has been done in controlling nematodes. Thrips and mites cause considerable damage to flowers and fruits but this is not considered as alarming. Aphids are widespread and cause damage by transmitting banana bunchy top virus (BBTV).

BBTV is widespread in the country, creating problems for producers. It is well known to the commercial growers and uprooting is being done to solve the problem. The virus-infected plants are neither burned nor buried, rather they are bulked at one side of the field which helps disease dissemination through carriers.

‘Sabri’, the second leading dessert variety is highly susceptible to fusarium wilt. This variety is now under threat of extinction. Because of soil-borne diseases, ‘Sabri’ cannot be cultivated for more than 3 years in the same areas. The use of disease-free planting materials and improved drainage system can prevent infection.

Most of the varieties of banana and plantain are susceptible to leaf-spot diseases. Tilt and Bavistin were found effective against this disease. However, farmers rarely spray on their plants. Tilt is being used only in commercial areas. Aside from these diseases, banana streak virus (BSV) and banana bract mosaic virus (BBrMV) have been identified but have not been given enough focus yet.

**Environmental factors**

Different banana regions are devastated by cyclones, drought, flood and cold temperature. The southern part of Bangladesh is cyclone-prone with occasional heavy production loss. The eastern part on the other hand is subjected to monsoon damage. In winter, the vegetative growth of banana is reduced and bunches are underdeveloped because of temperature lower than 20°C for about 2 months. The northern part also experiences drought for a long period. Most of the low-lying areas are affected by flood almost every year leading to production loss. In hilly areas, bananas are being grown under rainfed condition.

**Lack of disease-free planting materials**

Farmers are not aware of the sucker quality. Suckers are mostly collected from old orchards without knowing their disease status.
Lack of production technologies

Banana is a fast-growing crop. It requires water for its growth and fruit development. In commercial orchards, flood irrigation is done. In hilly areas, however, there is no available irrigation facility. Farmers also do not follow proper nutrient management. Banana has a high demand for potassium but farmers use more nitrogen and phosphorus resulting in nutrient imbalance. Effect of macronutrients on banana was studied at some locations but not of the effect of micronutrients. Intercultural operation such as weeding, desuckering, earthing up, pest management etc. are not done in homestead and hilly areas.

Postharvest management

The postharvest losses of banana in Bangladesh are high (20-30%). This is mainly due to the delicate nature of the fruit when it ripens and lack of suitable infrastructure for transport from production point to consumers. No processed products are marketed in Bangladesh. Due to rainfed cultivation, cyclones and monsoon storms, bananas have to be grown at the same period, resulting to oversupply in the market during harvest season. Natural ripening of banana is done for home consumption only. Heat treatment is the common method for ripening banana in commercial scale. Heating is done either by a candle or stove or by burning rice husk with banana covered with the polyethylene film or in a closed room for 6-20 hours depending on the season and variety. In this system, the firmness or texture of banana is partially damaged due to the high temperature created inside the polyethylene cover or the closed room. Fans are occasionally used to lower the temperature. About 10-15% bananas are damaged within a day due to overheating. Fruit colour also becomes pale. Some traders use ethrel to hasten ripening. They usually spray ethrel on the whole bunch before loading it in the truck for shipment to the market. Sometimes immature bunches are harvested, especially when there is higher market price. No processing industry for banana has been developed in the country.

Progress in banana R&D

Research activities

- Collection and evaluation of Musa germplasm. Twenty-three accessions were received from the International Transit Centre (ITC) in Belgium through INIBAP-AP. Fifteen of them were planted in the field for evaluation. ITC. 1441, ITC. 570 and ITC. 1320 were found to be promising.
• **Improvement of local cultivars.** ‘Bangla Kola’ (‘Kabri’) is a drought-tolerant cultivar and is being cultivated in the hilly areas without much care. A new line of this cultivar has been developed through clonal selection.

• **Maintenance of improved germplasm.** The introduced, released and commercial cultivars were maintained in the insect-protected nethouse.

• **Crop protection measures.** Sigatoka is a serious disease of banana. Knowin was found to be the best fungicide against sigatoka leaf spot. BARI has developed the technique of using polybag just before opening the first hand of the bunch instead of DDT and Sevin.

• **Conservation of germplasm.** The local cultivars were conserved onfarm in three locations.

**Development activities**

• FHIA-03 is performing well with respect to yield and cooking quality.

• Field days and training programmes were organized for the banana growers, NGOs and extension personnel involved in banana production.

• A good number of disease-free tissue-cultured plants of BARI Kola-1 were distributed to the farmers through BARI and NGOs laboratories (SQUARE, BRAC, PROSHIKA).

• A manual on banana production technology was published and distributed to the growers.

• A book on banana production was published in 2001 for distribution to the progressive growers.

**Ongoing banana R&D activities**

**Research activities**

• **Evaluation of improved varieties.** Preliminary selections of ITC accessions namely, ITC. 570, ITC. 1320 and ITC. 1441 were planted in farmers’ field in three locations to assess their performance and consumer acceptability.

• **Improvement of local cultivars.** Research emphasis has been given to the improvement of local cultivar Sabri through clonal selection.
- **Maintenance of improved germplasm.** The introduced, released and commercial varieties are being maintained in an insect-protected nethouse for sucker production. The virus-free suckers grown in the nethouse are being used in tissue culture laboratory for large-scale production of healthy plantlets.

- **Documentation of local banana cultivars.** Local cultivars were collected and planted at Ishurdi for characterization, evaluation and documentation.

- **Soil-nutrient management.** Only the commercial farmers use fertilizer but not judiciously. Most farmers use high amount of phosphorus and urea but low potash which is not appropriate for banana. Efficiency of organic fertilizer on banana production is being studied.

- **Crop-protection measure.** Sigatoka is a serious disease of Cavendish-type banana. Studies on screening of new fungicides against this disease are being done. There is a programme for collection and identification of nematode species in banana-growing areas.

- **Postharvest handling.** Emphasis has been given on postharvest research to reduce postharvest losses. Research is also being done to delay ripening.

**Development activities**

- Field demonstration on high-density planting of banana is being done by the Department of Agriculture Extension (DAE) in collaboration with OFRD, BARI.

- Field demonstration on the performance of BARI-released varieties BARI Kola-1 and BARI Kola-2 is being done by BARI.

- *In-vitro* multiplication of recommended and released varieties is being done for distribution to the growers. BARI and NGOs (SQUARE, BRAC, PROSHIKA) are involved in these activities.

- Field days and training programmes are to be organized for banana growers to equip them with modern production technologies.

**Institutions involved in banana R&D**

Research on banana is conducted at the Horticultural Research Centre, BARI under the NARS system. Bangladesh Agricultural University (BAU) and Bangladesh Sheikh Mujibur Rahman Agricultural University (BSMRAU) are also engaged in student-based research
activities on banana. DAE and NGOs play an important role on technology dissemination.

**Proposed areas of collaboration with BAPNET**

- Germplasm collection and conservation
- Establishment of virus indexing and tissue culture laboratory
- Disease management including management of nematodes
- Postharvest handling and processing technologies
- Manpower development through short-term training and visits
- Exchange of information on new technologies.
Overview of banana research in Cambodia

Men Sarom*

Banana is cultivated anywhere in the country stretching from the sea level to the highland regions, but it is predominantly found along the river banks and in the central and northeast highland regions of the country.

Banana plays a very important role in the daily diet of the Cambodian people. It is consumed fresh, but also eaten in processed forms like dried, boiled, fried and as cake. An economical and cultural crop, bananas are used in all religious and traditional ceremonies of the country. Regardless of the important contribution that bananas can play to the country’s economy, investment in banana research is still very limited.

Currently, the production of banana in Cambodia is still a small-hold industry. A constant threat to the expansion of the crop is the damage caused by pests and diseases, such as fusarium wilt among others.

Development of tissue-culture capacity

With a moderate funding support from the International Network for Improvement of Banana and Plantain (INIBAP) and with a strong commitment from the personnel of Cambodian Agricultural R&D Institute (CARDI), a banana research project in the country has been developed. This project initiated the development of capacity for tissue culture which can generate a significant number of banana plantlets for further field multiplication.

National repository

Cambodia is rich in genetic diversity of Musa. However, the fragility of the crop against vast changes in the world ecological conditions presents a strong need for their protection from permanent disappearance from the world. In this regard, the Cambodian programme took special attention on the issue, and significant progress has been made.

Collection

With funding support from INIBAP, 89 samples of traditional cultivars from three provinces, Kampong Cham, Kampong Thom and Kandal, have collected within the last 2 years (Figure 1). More collections will

*Director, CARDI, Phnom Penh, Cambodia.
be done in the other provinces, but because of financial constraints, work was temporarily stopped.

**Figure 1.** Collection sites of the traditional cultivars of banana in Cambodia. The sites are Kampong Cham, Kampong Thom and Kandal.

**Conservation**

All collected cultivars were planted in rows of 5 m spacing at the CARDI research field. Five plants of each sample were collected from the original sources and planted on bunds to avoid damage caused by water logging (Figure 2).

**Figure 2.** Banana field genebank at CARDI.

**Figure 3.** Screenhouse containing tissue-cultured banana plantlets for field.
Introduction

Along with the collected materials, a set of materials from the INIBAP Transit Centre (ITC) in Belgium was also received (Table 1). Unfortunately, because of limited experience in working with those small plantlets, a big number of plants in the set died in the screenhouse conditions. Only 19 plants survived and were transferred for planting in the field genebank with the collected traditional cultivars. Due to this situation, the same set of materials was again sent to us from Belgium. Compared with the first batch, this second batch of plantlets all survived in sub-culture conditions (Figure 3).

Multiplication

To produce a large number of plantlets for each accession, materials received from the International Musa Testing Programme (IMTP) are triple sub-cultured. These will then be transferred to the screenhouse for their first planting into the soil before sending to the field.

Field trials

As the number of plants from introduced material is still limited, no field trial has been initiated so far. However, with rapid progress in multiplying the materials through tissue culture, it is hoped that some on-farm testing trials can be planned for the year 2005. At least three locations of onfarm testing will be conducted in the 2005 rainy season.
Capacity building

Within the last 2 years, with a strong support from INIBAP, a number of staff from CARDI has been trained in various fields in banana research (Table 2).

Table 2. Trainings attended by Cambodian *Musa* researchers.

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Date</th>
<th>Location</th>
<th>Funding agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pith Khon Hel</td>
<td>Banana Workshop</td>
<td>Nov 2001</td>
<td>Sri Lanka</td>
<td>INIBAP</td>
</tr>
<tr>
<td>Thun Votany</td>
<td>International Training Course on tissue-culture techniques of banana</td>
<td>Dec 2002</td>
<td>Taiwan</td>
<td>INIBAP</td>
</tr>
<tr>
<td>Thun Votany, Sakhan Sophany</td>
<td>On-the-job training on tissue culture</td>
<td>2003</td>
<td>Taiwan</td>
<td>CARDI</td>
</tr>
<tr>
<td>Ny Vuthy</td>
<td>Workshop on <em>Musa</em> nematology</td>
<td>2003</td>
<td>Philippines</td>
<td>INIBAP</td>
</tr>
<tr>
<td>Pith Khon Hel</td>
<td><em>Musa</em> Germplasm Information System (MGIS)</td>
<td>Dec 2003</td>
<td>Malaysia</td>
<td>INIBAP</td>
</tr>
<tr>
<td>Pith Khon Hel</td>
<td>International Workshop on sustainable banana production through the use of healthy seedlings</td>
<td>Oct 2004</td>
<td>Vietnam</td>
<td>INIBAP</td>
</tr>
<tr>
<td>Thun Votany</td>
<td>Training on tissue culture</td>
<td>Jul 2004</td>
<td>Thailand</td>
<td>ASEAN/BIOTECH</td>
</tr>
</tbody>
</table>

Areas for collaboration

1. *Evaluation and selection of fusarium wilt-resistant variety.* Fusarium wilt is a serious problem in banana production in Cambodia. Availability of resistant cultivars against this disease will be of great help to the industry.

2. *Research on banana value adding.* Most of the time in the peak harvesting season, marketing is becoming a serious problem for the farmers. In this circumstance, banana can be processed and consumed as nutritious food.

3. *New production technologies.* New highly marketable banana cultivars, production management and other technologies are necessary for the banana production in the country.

4. *Human resources development.* Support in the field will provide a good foundation for banana research in the country.

Constraints

1. *Funding.* Despite the fact that banana is one of the major crops in Cambodia, funding sources, local and international, toward research on this crop is absent or very limited.

2. *Infrastructure.* Development of suitable research infrastructure within the country is possible a priority for a long-term mandate.
3. **Human resource development.** Limited skills in banana research in Cambodia is one of the major factors responsible for a slow progress in the development of the industry.

4. **Pest and diseases.** Many pests and diseases are found in the country which significantly affect the production and quality of the crop. Most predominant problems are fusarium wilt and nematodes.
**Banana research and production in China**

Xu Linbing*, Yang Hu, Huang Bingzhi and Wei Yuerong

Banana is one of the major fruits in China. In 2004, the total planted area for banana was 244 793. Some commercial plantations obtain 60 t/ha\(^{-1}\) yr\(^{-1}\). However, due to typhoon and chilling, the average yield is only at 22.7 t/ha (Table 1). The main consumption market is located in north China, amounting to 6 t/yr. Effective 18 June 2003, China is in Free Trade Area Agreement with the Association of Southeast Asian Nations (ASEAN). This opened up more opportunities for the country’s thriving banana export industry.

<table>
<thead>
<tr>
<th>Province</th>
<th>Area</th>
<th>Area (%)</th>
<th>Production (t)</th>
<th>Production (%)</th>
<th>Productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangdong</td>
<td>110.7</td>
<td>44.65</td>
<td>2 771 700</td>
<td>48.90</td>
<td>24.55</td>
</tr>
<tr>
<td>Guanxi</td>
<td>54.5</td>
<td>21.99</td>
<td>1 073 400</td>
<td>19.32</td>
<td>19.70</td>
</tr>
<tr>
<td>Hainan</td>
<td>34.1</td>
<td>13.76</td>
<td>853 700</td>
<td>15.36</td>
<td>25.01</td>
</tr>
<tr>
<td>Fujian</td>
<td>29.3</td>
<td>11.82</td>
<td>765 000</td>
<td>13.77</td>
<td>26.11</td>
</tr>
<tr>
<td>Yunnan</td>
<td>16.0</td>
<td>6.45</td>
<td>126 000</td>
<td>2.27</td>
<td>7.88</td>
</tr>
<tr>
<td>Guizhou</td>
<td>2.0</td>
<td>0.81</td>
<td>8 400</td>
<td>0.15</td>
<td>4.20</td>
</tr>
<tr>
<td>Sichuan</td>
<td>1.1</td>
<td>0.44</td>
<td>11 800</td>
<td>0.21</td>
<td>10.73</td>
</tr>
<tr>
<td>Chongqing</td>
<td>0.2</td>
<td>0.08</td>
<td>1 300</td>
<td>0.02</td>
<td>6.50</td>
</tr>
<tr>
<td>Total</td>
<td>244.8</td>
<td>100.00</td>
<td>5 557 300</td>
<td>100.00</td>
<td>22.70</td>
</tr>
</tbody>
</table>

**Banana industry promotion**

A project for the promotion of the banana industry was carried out by the China Agriculture Ministry, South Sub-tropical Crop Development Center (CAM-SSCDC) in 2002. Last November, a demonstration meeting was held in Hot Farm, Nanning, Guangxi. Hot Farm is one of the biggest banana plantations in China. It started with a plantation area of 67 ha in 1997 and later expanded to 1000 ha in 2004. To improve the productivity of Hot Farm, irrigation system, mechanization, cable way transport system and a packing house were set up. These all contributed to better price and quality of bananas. Hot Farm is now becoming a famous brand in China.

In order to extend the new technology to all banana plantations, CAM-SSCDC will launch a China Banana Network in Xuwen County,  

*Senior Agronomist, Guangdong Academy of Agricultural Sciences, Guangzhou, China.
Guangdong on 20 December 2004. There is a bumper harvest this year, with some farms having more than $20,000/ha average income. A China Fruit Marketing Association Banana Branch in Haikou, Hainan province was set up in June 2004 (Xu Linbing 2004a). This will improve the banana marketing system, build up the banana selling network, help the farmers sell bananas easier and earn more profit. Hot Farm, Jianfeng, Datang, Tianbao, Tongtian, Baiguo, Shanding, Fu Min, etc. are some of the most recognized brands (Yang Peisheng 2003).

Hainan Banana Association (HBA) was founded in April 2002. During the last 2 years, HBA helps the government develop the local banana industry. The first magazine in China, BANANA, is edited for extending new technology and information. HBA also put up a joint export base covering 2000 ha in cooperation with Fresh System Company, the biggest banana dealer in Japan. HBA has helped Lingao farmers to join a Banana Community (BC). The BC can obtain a loan from the bank to avail of the technology and marketing directed by HBA. For the first year, BC has covered 100 ha, and earned a $900,000 interest. It is estimated that the earnings of BC would double this year. HBA has also assisted the farmers to avail of insurance for the plantation in case of calamities like typhoons.

Guangdong Horticulture Academy Banana Science and Technology branch is another active group founded in 2001, which works on the banana industry.

**Market price analysis**

Good market price is a good motivating factor for the farmers to plant bananas. Data on this was collected from www.pyagri.gov.cn.

It can be seen from Figure 1 that in some months, the highest price appears to be twice more than the average price. Too many fruits competing with banana during summer lowers the banana rice. On the other hand, during winter, most of the plants die of chilling. The price gets higher than $0.5/kg following the next spring, of which the farmer can earn $20,000/ha profit in Hainan. Although there has been a recorded increase in production (Table 1), Figure 1 shows that the price did not change so much in the last 4 years.

Economic development increased the market demand for bananas. Postharvest technology made the shelf life of banana longer. The marketing network of banana is also extended to small towns. Overall, more people eat banana than before, with the consumption volume becoming bigger. It is estimated that the production will reach 7M t in the next 3 years.
Banana research and production in China

Banana production and research

Major pests and diseases

- **Sigatoka** is the most common disease in the undeveloped region (i.e. Hainan, Yunnan) during spring and fall. Four to five types of chemicals are sprayed yearly to control it. In 2004, Xie Yixian had studied the nucleic acid of banana sigatoka leaf spot disease pathogens in Hainan. Eleven isolates of banana sigatoka leaf spot disease pathogens from Hainan were identified using the polymerase chain reaction (PCR) species-specific primers. The result showed that 10 of the 11 isolates from Danzhou, Ledong, Wenchang, Dongfang, Chenmai, Lingao, Qunhai, Changjiang, Qunsan and Sanya in Hainan were *Mycosphaerella fijiensis*, while the isolate from Baisha was neither *M. fijiensis* nor *M. musicola*. Further studies should be done to identify this isolate. Random amplified polymorphic DNA (RAPD) analysis showed that the isolates were in two groups, which supported the result of the PCR identification. The results of this study can be used as a reference guide for the integrated management of banana Sigatoka leaf spot disease in Hainan (Xie Yixian 2004).

However, in developed regions such as Pearl River delta, leaf spot disease is no longer a problem for banana plantation. Leaf margin necrosis, where the the margin of the leaf turn light greyish brown and then dries up, is more common.

- **Leaf marginal necrosis.** Ten years ago, leaf marginal necrosis was found only in Machong town, Dongguan city (30 km from Guangzhou). However, at present, it is very common in Pearl River delta A possible reason for this are the influx of power stations, factories and vehicles which cause severe air pollution. According to 2003 report of Guangdong Environmental Protection Bureau, SO₂ is the main air pollution source. SO₂ contain 0.025 mg/m³ and goes up to 13.5%. The
rate of provincial de-sulfurization is only 13.30%. This then causes acid rain of more than 50% and the average pH of precipitation to be 4.92 (http://www.gdepb.gov.cn. 2004). The relationship of acid rain and banana leaf marginal necrosis is yet to be studied.

- **Banana Bunchy Top Virus (BBTV)**. Wei Hongyan (2004) studied the promoter activity of BBTV Zhongzhou isolate (BBTV-ZZ) DNA4 non-coding region. BBTV-ZZ DNA4 non-coding region (Po1), and its 5’ end deletion of CR-M (Po2), and deletion of CR-M and CR-SL (Po3) were subcloned by PCR and inserted into the upstream of GFP::GUS plant expression vector pCAMBIA 1304 to construct the recombinant plasmid pTA2, pC26 and pC45, respectively. Agrobacterium tumefaciens harbouring pTA2, pC26 and pC45, were respectively injected into leaves of the tobacco (*Nicotiana tabacum l. cv. Xanthi NC*) via agroinfiltration. Transient expressions of GUS and GFP determined in injected leaves were 1.007, 0.852, 0.939, 2.069 and 0.021 pmol·MU/(g·min), respectively. Values of absorbance of GFP in 1mg total protein from pTA2, pC26, pC45, pCAMBIA 1304 injected leaves and non-injected at 490 nm by indirect ELISA were 89.577, 65.184, 72.096, 100.440 and 3.287, respectively. The results suggest that Po1, Po2 and Po3 all have strong promoter activity. In transgenic tobacco plants, activities of Po1, Po2 and Po3 were restricted to the vascular associated tissue by the detection of GUS.

- **Cucumber Mosaic Virus (CMV)** is the main disease in farms planted with tissue-cultured seedlings. Aphid control in the nursery and young plant is very important.

- **Fusarium wilt** (*Fusarium oxysporum f. sp. cubense*) (Foc) has become the main disease for some banana plantations in Southern China. Guangdong has set up a project to control it. The involved institutions include South China Agricultural University, Guangdong Academy of Agricultural Sciences (GDAAS), Chinese Academy of Tropical Agricultural Sciences (CATAS), Fujian Agricultural and Forestry University, Hainan Academy of Agricultural Sciences and Guangzhou Institute Agricultural Sciences. Xu Wenyao studied the pathogenic reaction of banana pseudostem cells to different races of vascular wilt fungus and their crude toxins. It describes the pathogenic reaction of the banana cells upon the inoculation of spore suspension and crude toxins of Foc. The detached pseudostems and pseudostem cells of banana plantlets were treated with pathogen spore or crude toxins solutions. The pathogenic reactions were observed by using tissue sectioning. The results showed the same reactions, such as browning reaction, upon the inoculation of crude toxins produced by different fungal races. This suggests that the virulence differentiation of Foc was
Banana research and production in China
determined by some unknown factors rather than the toxins specificity. It was also proven that the toxins produced by Foc are non-selective for banana (Xu Wen-yao 2004). The Foc was found to have not only destroyed Fenjiao (ABB, Pisang Awak), but also Baxi (AAA, Cavendish) in Qiongshan and Sanya, Hainan province. The disease area covered 43.33 ha and 6.67 ha respectively. This is a big potential problem for the banana industry in Hainan (Zhou Chuan Bo 2003).

Fengjiao (ABB, Pisang Awak) is the popular variety in China. The price is usually higher than Cavendish. It is very susceptible to Foc in commercial plantations. The ratoon harvest, which is 60-80% in virgin land, may fall to 0%. But in some backyards, Fengjiao can harvest many crop, and last for many years.

Integrated pest management may cause no harm to the roots and sucker since no chemicals/pesticides will be used. Further studies are needed on this IPM programme.

Twenty-three accessions from the International Musa Testing Programme (IMTP) were propagated, rooted and planted in Wangqingsha IMTP station on 31 March 2004. These accessions were investigated for the presence of Foc. Based on the last assessment conducted on 14 October 2004, FHIA-01 (AAAB), FHIA-02 (AAAB), FHIA-18 (AAAB), FHIA-25 (AAAA) are resistant. Meanwhile, 10% of FHIA-03 (AABB) and GCTCV 119 (AAA) and 12.5% of CRBP39 (AAAB) are affected. More detailed studies will still be done.

• Banana Anthracnose. Zhu Sijiang (2004) investigated the induction of disease tolerance of postharvest banana by using crude extract from peels of green banana. Dipping postharvest banana in crude extract from peels of unheated green banana (UHGB) significantly controlled the occurrence of banana anthracnose, while dipping in crude extract from peels of heated green banana (HGB) had little effect on fruit rotting. This is the first report on the induction of disease tolerance of postharvest fruits by direct application of crude extract from fruit of the same species. UHGB-treated anthracnose (Colletotrichum musae) spores were found to be less virulent than HGB-treated ones. While HGB affected spore germination, more than UHGB, lesser anthracnose was observed on UHGB treated fruits. These results imply that the mechanism of anti-disease substances extracted from green banana peel to enhance the disease tolerance of post harvest banana by exogenous application lies in the fact that the anti-disease substance help strengthen the defensive system of the fruit itself instead of affecting the pathogens (Zhu Si-jiang 2004).

Genetic divergence among 38 strains belonging to the falcate-spore
species of *Colletotrichum* was assessed by RFLP analysis on the basis of rDNA ITS region. The PCR amplified ITS region (ITS-ITS5) was about 650 bp in length in all the tested strains. RFLP patterns of ITS products digested with different endonucleases (*Alu* I, *Bsu* R, *Hin* 6 I, *Hpa* II and *Taq* I) were not distinguishable within the same species, but clearly different at the interspecies level. UPGMA analysis of co-migrate band in restriction patterns showed that 38 isolates could be divided into six distinct groups. Some strains previously in the different species, such as *C. truncatum*, *C. circinans* and *C. capsici*, were closely grouped together in a cluster dendrogram, indicating that they possibly belong to the same species (Zeng Daxing 2004).

- **Bacterial corm rot** was found in Hainan. It is caused by *Erwinia carotovora*. It occurred on poorly drained fields during the rainy season, 3%-7% plants were harmed (Zhou Chuanbo 2004).

**Environmental factors**

- **Chilling** in winter is one of the main restraining factors of banana production. Compared with apple, pear and citrus, the area planted to banana is very limited in China. However, the quality of Chinese bananas is better than tropical bananas, thereby attracting Japanese buyers to come to China. HBA is pushing a big company to join together to supply the Japanese market but typhoons and summer made banana production unstable. Some farmers moved their business to Xisuanbanna, Yunnan province. The province has the best environmental condition in China, without typhoon, with a tropical climate which lies 400 m above sea level. The banana is sweet all year round because even during summer, the temperature is remains at 20°C at night and 37°C in the afternoon. The road condition, however, is not that good but will be improved with the opening of the Kunming-Bangkok express way in 2007. This will also benefit Thailand and Laos. It is expected that they will bring their tropical fruits to the Chinese market.

- In 2004, Chen Jiahao has studied how the defense effect of smoke screen on low temperature injures banana. The results showed that smoke screen prevented radiation of low temperature. The lower the air temperature was, the better the heat preservation effect was. The heat preservation effect was stronger at the densest height than at any other heights in the banana plantation. The heat preservation effect of smoke screen was not significantly affected by sky conditions (sunny or overcast) and air humidity.

- **Typhoon** is another major limiting factor in banana production. In 2003, more than six typhoons devastated the banana regions. On 17
November 2003, Typhoon Nibert wiped out half of Hainan’s banana plantation, causing an estimated loss of 1 billion yuan ($120M). Fortunately, in 2004, no typhoons landed on Guangdong, Hainan and Fujian provinces. The production in 2004 therefore increased by 20%. To minimize production loss due to typhoons, most plantations use timber and bamboo props to minimize the effect of strong winds. Approximately 100 M of timber and bamboo are used yearly. This is a great loss for the forests in China. In order to save timber, a timber preservation research project was carried out by the Guangdong Forest Research Institute. This project was sponsored by the International Tropical Timber Organization (ITTO). The vacuum-pressure system in the pilot workshop was set up to treat timber. They developed a new formulation for mold control, which showed good efficacy after being tested. The treated timber for banana standing pole is one of the demonstration programmes. Four-year tracking analysis results indicated that the timbers are still in good condition. It is estimated that the timber can last 15-20 years, about 3-4 times longer than the untreated ones. If the project is extended to 50% of the banana plantations, more than 70% of timber will be saved.

Xuwen County is situated in the cape of Leizhou Peninsula, west Guangdong. It is a tropical region, afflicted by drought which causes a stress to banana plantations. Some farmers usually dig deep wells (200-400 m deep) and pump water for irrigation. The 2-3 hours/8 days irrigation belt system is adapted. In Hainan, irrigation is for 1 hour/6 days, while in Pearl River delta, it is 20 minutes/3 days. The optimal plot for irrigation should be tested respectively. At present, this irrigation belt system has been extended to up to more than 30 000 ha in China. However, over excavation of underground water will cause the water table fall. It is said that the water table dropped to up to more than 100 m in Ledong, Hainan during the last 2-3 years. The use of underground water should be studied further.

**Standardization**

The Chinese government is setting up standards to promote banana production. This includes environment management, plantlet care and production, field management, postharvest processing and fruit quality.

**Germplasm**

Of the collections held in GDAAS, about 50% accessions were characterized and entered into the MGIS database. Chen Houbin has
evaluated fruit characteristics of 28 Cavendish subgroup banana cultivars. The result showed that the bunches of ‘Gaojiao Dundilei’, ‘Williams’ and ‘Baxijiao’ were more cylindrical while those of dwarf Cavendish were more conical. Yields of the planting crop and the first ratoon were 20-30 kg and 30-35 kg per stem, respectively. ‘Aijiao Dundilei’ had the highest yield of 33.8 kg per stem in two crops, 21% higher than the introduced cultivars like ‘Baxijiao’ and ‘Williams’. Number of hands varied between 7 and 9, with the total fingers 140 to 170. The first hand consisted of 25 to 30 fingers and weighed 4 to 7 kg in a bunch, which was double to triple that of the last hand. Finger length of the first hand was 20 to 22 cm whereas finger diameter was bigger than the normal standard (around 40 mm). A few local cultivars like ‘Aijiao Dundilei’ and Gaojiao Dundilei’ were comparable with the introduced cultivars in terms of yield, bunch shape, finger length and shape.

The germplasms were collected in Xisuanbanna Botanical Garden, Menglun, Yunnan province, (101°25´ EL; 21°41´ NL, 570 m above sea level, with a yearly average temperature of 21.5°C and precipitation of 1560 mm). Seven accessions were collected, 1 Shuguo Bajiao; 2 Teai Guanye Xianagjiao(AAA); 3 Taiyin Hongyebei Guanye Xianagjiao; 4 Pinhonghua Guanye Xianagjiao; 5 Xiangmin Xiaoxianagjiao (AA); 6 Heliconia aurantiaca Ghissbr; and Xiangtui Jiao.

**Breeding and selection**

- **Biotechnology breeding.** Xu Chunxiang (2004a) had experimented on the embryogenic callus starting from immature male flowers in two out of five banana cultivars and starting from scalps in two out of three cultivars. These four cultivars belonged to *Musa* AAA group. The frequency of embryogenic cell induction depended on genotype, cultivar and incubation condition. Embryogenic cell suspensions (ECSs) were initiated successfully from the embryogenic callus of all these four cultivars. The possibility of getting ECSs from embryog was also cultivar dependent. Xu Chunxiang (2004b) also regenerated Grand Naine plant through somatic embryogenesis. Grand Naine ECSs were plated on RDI or M3 medium for the regeneration of somatic embryos, 1 to 2 weeks after last subculture. The first regenerable somatic embryos were observed approximately 3 weeks after inoculation. After 8 weeks of culture, the embryogenic mass had increased about 5 to 18 times. The number of somatic embryos that could be regenerated from 1 ml settled cell volume (SCV) of ECSs ranged from between 0.71×10^5 and 3.07×10^5, depending on pre-culture time in liquid medium before regeneration, regeneration media and incubation conditions (light/
dark). The frequency of plant recovery and the amount of plantlets from 1 mL SCV of ECS were indirectly affected by the somatic embryos regeneration conditions that were studied.

Different protocols for establishing embryogenic cell suspensions and plant regeneration for gene transformation were also studied. Main cultivars and important germplasm in China, such as *Musa itinerans* Cheesm., *Musa* AA Pisang Mas cv. Mas, *Musa* AAA Cavendish cv. Baxi, and *Musa* AAB Silk cv. Guoshanxiang were used as experimental materials to establish their embryogenic cell suspensions. Different explants, immature zygotic embryo of *Musa itinerans* Cheesm., immature male flower of *Musa* AA Pisang Mas cv. Mas and scalp of *Musa* AAB Silk cv. Guoshanxiang were used to induce embryogenic callus, and embryogenic cell suspensions of these cultivars were established. Histological analysis was performed and used to prove that the single-cell origin of somatic embryos was derived from immature male flower of Mas (AA). Embryogenic cell suspensions of Mas were cryopreserved successfully by vitrification, and its protoplast culture was processed (Wei Y R et al. 2004b).

- **Space radiation breeding.** Three clones (B5, B2, Guangfeng No.1) are sent to space by return satellite. Only B5 was alive when it returned. The bud tissue was then cultured in vitro. It grows faster than normal and more mutated buds, like globosity embryogenic callus and cancer buds. The first group of plants (11 normal buds’ plants, 8 cancer buds’ plants, 9 control plants) was planted in greenhouse on 9 May 2004. Now that the plants are shooting, there are no differences between them. The second and third groups were planted in Dongchong station on 7 and 30 July 2004. The cancer buds’ plants showed more off-type leaves. The agronomic traits are being observed by GDAAS.

- **Somatic mutation screening** is being used by GDAAS. Daguo No.2 (AAA Cavendish) screened from Guangdong No.2 was tested in Dongguan, Panyu. The results showed that the fingers were 1.4 cm longer, finger weight was 32 g higher and bunch weight was 4.4 kg higher than Guangdong No.2. Compared with the popular cultivar Baxi, Daguo No.2 showed a finger weight which was 22 g heavier and had a more robust pseudostem. After typhoon Dujian (2 September 2003), Daguo No.2 was damaged by 1.7% compared with Baxi which was damaged by 54.9%. Daguo No.2 however has a very poor taste. The second new clone Dafeng No.1 (AAA Cavendish) was screened from local Cavendish Dazhong Gaoba. It was shown that the finger was 1.6 cm longer, finger weight was 30.5 g heavier and bunch weight was 2.1 kg heavier than Baxi. However, its bunch shape is not very good. The third clone Changfeng Xiangjiao(AAA Cavendish) which
was screened from Williams, showed that the finger was 2 cm longer and bunch weight was 16 kg heavier, than other Williams, respectively. Compared with the popular cultivar Baxi, Changfeng Xiangjiao does not differ with Baxi in terms of plant characteristics except that its finger is 1.6 cm longer. Another Awak mutation, Ai Fenjiao (ABB Dwarf Pisang Awak) is 2-3 m in height, its shooting cycle 1 month shorter than normal one but the yield is low at 10 kg/bunch.

**Tissue culture**

Tissue-cultured plantlets are now becoming a very popular planting material. Most plantations grow tissue-cultured crops. However four problems have remained: (1) tissue-culture laboratories do not have isolated screenhouse for mother plants; (2) sample check for proliferating tissue quarantine is not sufficient and not fast enough; (3) most of the hardening nurseries do not have a net for isolation and are located near a diseased banana plantation; (4) poor nursery management of tissue-cultured plantlets made fusarium wilt spread rapidly. Huang Youbao (2004) has however introduced countermeasures for these problems encountered. These are: (1) to build up a mother plant nursery; (2) proper management of tissue culture source: location of mother plant for sucker and quarantine must be checked; (3) proper management of tissue culture nursery. Nurseries should be 50 m away from vegetable and banana field. There should be a net house and buffer space. Fields must be weeded and disinfected, clean water source should also be used.

**Nutrition**

The banana specific fertilizer becomes more popular than ordinary compound fertilizer. According to the plant growth stage, N:P:K content is adjusted, including vegetative-growth fertilizer, flower differentiation fertilizer and fruit-growth fertilizer. Bio-fertilizer (organic) is adapted in many plantation. Amino-acid leaf fertilizers are also popular this year.

**Postharvest**

Recently, many plantations have simple packing houses which are built by the local government and the farmers in Hainan province. Cartons are used to pack bananas instead of the usual bamboo baskets. There are new cable ways for banana transport built in Zhongshan and Guangxi in 2003. Hot Farm for example, has a re-fixable cable way to
transport bananas. A 4000 m length way costs $25,000, but after the harvest season the facility can be put in the warehouse to avoid any damage.

Feng Dou (2004) analyzed the ethylene receptor gene cloning and expression in banana fruit. Using a total RNA from banana fruits as template, two different lengths of cDNA fragments were specifically amplified by RT-PCR, which revealed a significant homology to the reported ethylene receptor gene (Gene bank number: AF 113748). One cDNA clone (the longer one) showed 99% of homology to the ORF (open reading frame) sequence of the ethylene receptor gene, while the shorter cDNA clone displayed 97% identity but with a missing region corresponding to nucleotide 194 to 1036. Analyses of expression profile by RT-PCR of the cloned genes demonstrated that its expression was prominent at different developmental stages of ripening banana fruit. In contrast, their expression in the roots and leaves was non-detectable. The result of southern hybridization showed that this gene sequence existed as a single copy in the banana genomic DNA. The results indicated a fruit tissue-specific expression pattern of the cloned ethylene receptor cDNA. The cDNA truncated from ethylene receptor was probably generated through alternative splicing, and therefore might represent a novel form of ethylene receptor gene in banana.

Problems encountered and proposed areas of collaboration

Single cultivar planting would be a potential risk for banana production. Cavendish occupied 89% of production. However, Cavendish is very susceptible to Sigatoka and fusarium. Breeding disease-resistant cultivars is urgent.
1. Banana processing should be emphasized. Processing technologies must be developed.
2. IPM must be developed for export bananas since use of chemicals is strictly checked in the export market. IPM would be very helpful for the export banana plantations.
3. National banana production coordinating system should be set up (Yang Pei-sheng 2003). A China Banana Network will be launched at Xuwen, Guangdong on 20 December 2004.
4. Cooperate with international banana companies regarding marketing management.
5. Banana standards should be promoted to the farmers in the banana regions. Fruit quality should be improved. The taste of Chinese bananas is good, but the appearance is not. If the fruit appearance is improved, the Chinese banana could become best in the world market.
References


Banana and plantain R&D in India

M.M. Mustaffa* and S.Sathiamoorthy

Bananas and plantains are grown in India from Vedic times and mentioned in Tamil literature dating back to 120 BC. They are cultivated from coastal plains, deltaic areas and deep inlands to hills with an altitude of 1800 m. The system of banana cultivation varies among regions, garden land system, wetland system (in high-level deltaic areas only) and perennial systems (hills and plains).

In the garden land system, bananas are planted annually and ratooning is practised occasionally. In high-level deltaic regions, they are grown in wetland condition rotated with paddy. Under this system, annually replanting and ratooning are practised. This type of crop rotation minimizes soil-borne pathogens affecting bananas.

Under perennial banana growing system, there is no annual replanting of bananas. Plants are grown up to 50 to 75 years in the “Padugai” lands in plains. In hills with an altitude of 1000 to 1200 m, they are grown as either a solo crop or a shade crop for coffee. Most bananas are grown under rain-fed condition, under perennial system of cultivation. Mostly Pome types of bananas are grown.

Significant R&D

Crop improvement

A new *Ensete* species from Kodaikanal hills and a new diploid *Musa acuminata* from Anaimalai hills were collected, with the latter being found to be free from leaf spot diseases. Sixty-one exotic collections have been added to the INIBAP Transit Centre in Leuven, Belgium through National Board for Plant Genetic Resources in New Delhi.

Twenty accessions were characterized using, “Musa descriptor’ from INIBAP/IPGRI, Rome and added to the National Research Centre for Bananas (NRCB) database. RAPD marker analysis of wild *Musa balbisiana* from Andaman and Nicobar Islands exhibited 81.65 percent polymorphism among the amplified markers showing two major clusters as: (i) 16 types of wild *Musa balbisiana* subspecies from Indian mainland; (ii) 13 wild types from Andaman and Nicobar Islands (Figure 1). The existence of considerable variation was observed not only at the genome level but also with the geographical distributions.

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*Principal Scientist, NRCB, Tiruchirapalli, Tamil Nadu, India.*
However, the collections in the Indian mainland from western ghat to north eastern states also exhibited genetic relatedness, suggesting that the place of origin for *Musa balbisiana* could be one common place but diversified in three different regions like western ghat region of Kerala and Karnataka States, eastern ghat in Andhra Pradesh and Orissa and north eastern states. Andaman and Nicobar could be another centre of origin and diversity parallel to Indian mainland.

**Figure 1.** Dendrogram showing genetic relationships among 29 wild *Musa balbisiana* diploids using UPGMA cluster analysis.

**Clustering pattern of Mysore subgroup accessions**

The genetic diversity and phylogenetic relationship were analyzed for 36 accessions. Primers OPA-11, OPC-17, OPD-06 and OPD-18 produced polymorphism (Figure 2). The tree matrix clearly indicated five major clusters (Table 1).
Figure 2. Dendrogram showing genetic relationships among 36 Mysore (AAB) group accessions using UPGMA cluster analysis.

Table 1. Clustering pattern of Mysore subgroup accessions.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
<td>Chandan, Poovan, H-2 Kottavazhai, Jatikal, Champa, Chakkara Kunnan, H-2,</td>
</tr>
<tr>
<td></td>
<td>Alpon, Poovan, Karpura Chakkarakeli, Cheni Champa, Garo Moina, Dasaman,</td>
</tr>
<tr>
<td></td>
<td>Mysore Kudali, Lalvelchi, Palayankodan</td>
</tr>
<tr>
<td>Cluster 2</td>
<td>Borchampa</td>
</tr>
<tr>
<td>Cluster 3</td>
<td>Terabun, H-2, Motta Poovan, Soneri, Poovan, Ladia Champa, Poovan, Pisang</td>
</tr>
<tr>
<td></td>
<td>Ceylan, Chandra Bale, Mysore Bale, Mysore, Champa, Chandra Bale, Poovan,</td>
</tr>
<tr>
<td></td>
<td>Cheni Champa, Pisang Ceylan</td>
</tr>
<tr>
<td>Cluster 4</td>
<td>Pisang Ceylan</td>
</tr>
<tr>
<td>Cluster 5</td>
<td>H-2</td>
</tr>
</tbody>
</table>

Clustering pattern of Pisang Awak (ABB) sub group accessions

The genetic diversity and phylogenetic relationship were analysed for 43 accessions. Primers OPA-11, OPC-17, OPD-06 and OPD-18 produced polymorphism (Figure 3). The tree matrix clearly indicated two major clusters and cluster 2 with four minor clusters (Table 2).
Table 2. Clustering pattern of Pisang Awak (ABB) sub group accessions.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster 1</td>
<td>Boothi Bale</td>
</tr>
<tr>
<td>Cluster 2 a</td>
<td>Agni Malbhog, Kanthali, Nepali Vannan, Gouria, Kanchi Kela</td>
</tr>
<tr>
<td>Cluster 2 b</td>
<td>Deshi Kadali, Kanchi Kela, Mas, Octoman, Boddida Bukkisa, Dakshin Sagar, H-6, Moutman, Vella Palayankodan, Poombidiyan, Ban Kela, Ankur-II, Ladisan, Boothibale, Ankur-I, Shahi Baig, Eni Komban, Amrithapani, Dinamalakol, Gera, Chinia, Enna Benian, Shail Kela, Calananul, Vannathurpurani, Boothi Bale, Battisa Piro, Bhurkel, Karpouravalli, Jammulapalem Collection, Karpouravalli, Geda, Bhurkel, Mas</td>
</tr>
<tr>
<td>Cluster 2 c</td>
<td>Bhurkel, Chinia</td>
</tr>
<tr>
<td>Cluster 2 d</td>
<td>Karpuravalli</td>
</tr>
</tbody>
</table>

Figure 3. Dendrogram showing genetic relationships among 43 Pisang Awak (ABB) group accessions using UPGMA cluster analysis.

Genetic diversity in 28 genotypes of banana has been studied using RAPD markers. Among a total of 60 bands, the dendrogram showed two main clusters that differentiated all AA genotypes from the BB types. The BB group in turn had two nodes with both wild M. balbisiana types in one group and the cultivars ‘Cuba’, ‘Monthan’, ‘Karpouravally’ and ‘Muthia’ (ABB group) in another group has shown very close relationships. The hybrid M. acuminata x M. balbisiana was placed between these two groups. The cultivar Klue Teparod (ABB) was found to be placed along with the cultivar Red Banana (AAA).
Genetic diversity in 28 genotypes of banana has been studied using RAPD markers. Among a total of 60 bands, the dendrogram showed two main clusters that differentiated all AA genotypes from the BB types. The BB group in turn had two nodes with both wild $M. \text{ balbisiana}$ types in one group and the cultivars ‘Cuba’, ‘Monthan’, ‘Karpoooravally’ and ‘Muthia’ (ABB group) in another group has shown very close relationships. The hybrid $M. \text{ acuminata} \times M. \text{ balbisiana}$ was placed between these two groups. The cultivar Klue Teparod (ABB) was found to be placed along with the cultivar Red Banana (AAA).
Grouping of cultivars such as ‘Veletan’, ‘Ney Poovan’ and ‘Rasthali’ from South India lies far away from the BB group. This could be due to the involvement of other *Musa* species in their genomes. However, this still needs further investigation.

Genetic diversity in 22 genotypes was studied using ISSR primers. Among the 99 bands, the dendrogram showed three main clusters that differentiated all AA genotypes from the BB types.

It was observed that five ISSR primers amplified bands specific to “B” genotype and one ISSR primer also showed bands specific to “A” genotype. They were sequenced for development as SCAR markers. These have a potential in deciphering the genome composition of natural hybrids in banana.

Five ABB and eight BB accessions were screened for banana streak virus (BSV) integration by using four BSV activable sequences from B genome received from QDPI, Australia. These were BSV-OL (from cultivar Red Deccan), BSV-GF (from cultivar ‘Gold finger’), BS-Mys (from cultivar Mysore) and BSV-IM (source not mentioned). Integration of BSV-IM sequence was detected in all the accessions, while other activable sequences were present in most of the accessions. Another experiment will have to be done to confirm this.

In order to develop markers linked to fusarium wilt resistance, DNA isolated from the parents *M. acuminata*, Kadali and Hoobale and hybrids obtained from the crosses were amplified using random primers. Some bands specific to hybrids and resistant parents have been obtained. These have been cloned and sequenced for use as SCAR markers.

**Gene expression**

The activity profiles of the enzymes polygalacturonase (PG), cellulase, pectin methyl esterase (PME) and sucrose phosphate synthase (SPS) showed that there was increase in PG and cellulase activities in banana (cvs. Robusta and Ney Poovan) and SPS (in case of banana) indicating enzymatic degradation of cell-wall materials concomitant with ripening. However, PME activity registered an almost opposite trend with the activity declining with the onset of ripening. With onset of ripening, SPS activity increased initially, declined slightly and remained constant thereafter.

Primers have been designed to isolate ripening-related genes in banana using already available sequence data for cellulase, PG, PME, β-galactosidase (cell wall hydrolases), ACC oxidase, ACC synthase (ethylene biosynthesis enzymes) sucrose phosphate synthase (sugar
metabolism) and expansin (cell wall loosening protein). Partial length of cDNA clones has been obtained for all these genes using primers in banana. Fifteen ESTs have also been generated from fruit cDNA library of banana variety Mysore Poovan. Expression of beta-galactosidase and ACC oxidase was studied in ripening banana fruit. While beta-galactosidase was expressed at all stages of ripening, while ACC oxidase was expressed only during the initial stages of ripening.

Full-length genes of SPS, ACC oxidase, ACC synthase and PG have been isolated from banana vars. Robusta and Ney Poovan through RACE-PCR. Both of the 5’ and 3’ RACE-PCR products obtained were cloned and sequenced. Complete sequence of ACC oxidase gene from banana varieties Robusta and Ney Poovan has been determined.

In order to isolate fruit specific promoters, upstream regulatory sequences of ACC synthase and ACC oxidase genes have been isolated from banana cv. Robusta using genome walker kit. Four upstream sequences of ACC synthase gene of 1300 bp, 900 bp, 600 bp and 550 bp and one upstream sequence of ACC oxidase gene of 1100 bp have been isolated and cloned.

The 1206 bp upstream regulatory sequence of ACC synthase gene isolated from banana cv. Robusta has been analyzed. This promoter sequence was cloned into a promoterless vector and was shown to have promoter function through demonstration of GUS gene expression in transformed cowpea embryos. This is the first promoter sequence isolated from banana fruits from India to be registered in the NCBI database. There are only two other banana fruit promoter sequences registered in the database so far.

**Evaluation of Musa germplasm against banana stem weevil, Odoiporus longicollis under laboratory conditions**

Seventeen accessions belonging to triploid category were evaluated against stem weevil under laboratory conditions. Minimum feeding was recorded in accessions number 0265 (14.9%) and maximum feeding was recorded in accession number 0395 (45.8%).

**Screening of germplasm against sigatoka under field conditions**

Screening of 700 accessions against sigatoka leaf spot diseases using INIBAP guidelines resulted in the identification of nine immune accessions viz., Kalibun (AAB)-0574 and 0133, Dudhsagar (AAB)-0374, Pisang Rajah (AAB)-0217, Kalibow (AAB)-0211, Pisang Seribu (AAB), Thiruvananthapuram (AAB)-0125, Thiruvannanthaspulam (AAB)-0031 and Klue Teparod (ABB)-0253.
Screening of germplasm against nematodes

Eighty-five banana varieties were screened for their reaction to root lesion nematode, Pratylenchus coffeae and root-knot nematode, Meloidogyne incognita, in pots under greenhouse conditions. The results revealed that Singhlal, Sakkarachayna, Malaikali, Manikchampa and Karthobiumthamg were resistant to root-lesion nematode.

Evaluation of IMTP accessions against fusarium wilt disease (race 1 and 2)

Twenty accessions were evaluated under pot-culture condition. Eleven accessions viz., FHIA-17, FHIA-23, GCTCV-119, GCTC-215, Pisang Jari Buya, Calcutta-4, PA-03, Pisang Mas, Cultivar Rose, Yangambi km-5 and Pisang Ceylon were resistant. Pisang Lilin showed wilt disease symptoms (score-2).

Three promising selections of NRCB were evaluated at eight different locations including Tripura State. The performance of NRCB Sel.01 has been found very promising.

Establishment of embryo culture

MS medium and modified MS medium with higher concentrations of colchicine (10 mM) and knudson medium at lower concentration of colchicine hastened the development of embryos. Athiakol colchicine on the other hand suppressed the embryos’ development.

Direct regeneration of shoots from male floral hands of banana

Banana diploid cvs. Anaikomban (AA) and Kanaibansi terminal male flower bud were used to regenerate shoots directly from the floral hands and multiply banana shoots. The floral hands below 0.5 cm produced shoot buds while the bigger floral hands differentiated into full flowers. They did not produce any shoot buds or shoots. An increase in the concentration of benzylamine purine BA increased the percentage of response and the number of shoots produced increased to 5 mg/l BA concentrations.

Production

Application of 2.5 kg compost + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure plant⁻¹ at 3rd, 5th and 7th month after planting recorded the maximum plant-growth parameters and bunch parameters in both Karpuravalli and Rasthali bananas. Maximum bacterial population (56.33 X 10⁸ CFU) and fungi (14.33X 10⁶ CFU) were also recorded under organic cultivation. Conventional planting (1.8 x
1.8 m) with 75% N and K fertigation in Robusta (AAA), Rasthali (AAB) and Saba (ABB) resulted in maximum plant height and maximum average leaf area. Under a high pH soil, soil application of Fe (as 5 g ferrous sulphate/plant) with foliar application of Zn (as 0.5 % zinc sulphate) and B (as 4 ppm Boric acid) recorded highest growth and bunch parameters with high quality fruits. Application of distillery effluent (DE) at 30 000 l/acre along with 80% of recommended potassium (K) recorded higher bunch weight. Integration of CKFD @ 0.5 kg/plant and DE at 30 000 l/ac with 60% of recommended K gave an additional profit of US$627.85 to 31 750 per hectare in Karpuravalli and Ney Poovan banana respectively.

Protection

Two new minor pests were reported in banana. Chlorpyrifos + liquid paraffin + adjuvant impregnated bunch-cover has eliminated rust thrips infestation. Bunch covering also reduced the harvest time and improved the finger colour. Four bio-control agents viz., *Pseudomonas fluorescens*, *Bacillus subtilis*, *Paecilomyces lilacinus* and *Trichoderma viride* were effective in inhibiting the hatching of root-knot nematodes. *Bacillus subtilis* showed better colonization than others.

Non-pathogenic isolates viz., *F. oxysporum* –1 and *F. oxysporum* –2 were found to control wilt disease. Ethyl acetate fractions from *Solanum* spp. recorded maximum inhibition against both *Colletotrichum musae* and *Botryodiplodia theobromae* under *in vitro* condition. *Trichoderma pseudokoningii* and *T. viride-RT* were effective in inhibiting the mycelial growth of the crown rot pathogen, *B. theobromae*, under *in vitro* conditions. *Pseudomonas syringae* 1, *Pseudomonas syringae* 2, *P. caryophili*, *P. aeruginosa*, *Pseudomonas syringae* 3, *P. viridiflav* and *Bacillus cereus* were found to inhibit the crown rot pathogen. A method of mass production of *Trichoderma viride* using rice chaffy grains has been developed and standardized for mass production of *Trichoderma* by farmers themselves.

A duplex PCR has been developed for detecting BSV and BBTV simultaneously. RT-PCR technique is for detecting Banana Bract Mosaic Virus. Nucleic acid spot hybridization technique, on the other hand, has been standardized for detecting BBTV.

The mealybug *Ferrisia virgata* was found to transfer BSV among bananas. The virus was detected in the mealybug by PCR technique. A non-radioactive probe has been made for part of the BSV genome. One RAPD marker has been identified for differentiating the BSV infection or integration in Poovan. The DNA of BS Virus from Poovan plants was isolated and used for amplification of six partial segments.
The six PCR products were cloned in p-GEM-T vector and the clones have been sequenced. BBTV cp gene also cloned and sequenced for the Indian isolate.

Postharvest
The storage life and quality changes studied on mature Rasthali banana by using vacuum sealed 400 gauge poly-bags and stored at 13.5°C showed that the vacuum-sealed fruits had 40 days of green life at 13.5°C; but failed to ripen when shifted to ambient condition after 20 days of storage at 13.5°C. Those sealed normally in polybags had a green life of 8 days. The control had 10 days green life. Modified atmosphere packaging of Rasthali banana could control the chilling injury in Rasthali banana even at 10°C. The control exhibited chilling injury even at 13.5°C after 2 weeks of storage.

The fermented banana pickle was developed using Monthan banana.

Activities of various ripening related enzymes viz. PG, cellulase, PME and SPS were standardized after trying out various procedures including the use of acetone powder.

The activity profiles of the enzymes showed that there was an increase in PG and cellulase activities in banana (cvs Robusta and Ney Poovan) and SPS indicating enzymatic degradation of cell-wall materials concomitant with ripening. However PME activity registered an almost opposite trend with the activity declining with the onset of ripening. SPS activity, after recording initial increase with onset of ripening, declined slightly and remained constant thereafter.

The content of total soluble protein did not vary during ripening. Protein profiles however, showed qualitative and quantitative changes during ripening of banana fruit. The total sugars and reducing sugar increased with ripening in banana.

Extraction methods for RNA have been standardized after trying several protocols. Total RNA was extracted from both unripe and ripe banana fruit tissue. The quality and yield of RNA was found good.

Primers have been designed to isolate ripening-related genes in banana using already available sequence data for cellulase, PG, PME, β-galactosidase (cell-wall hydrolases), ACC oxidase, ACC synthase (ethylene biosynthesis enzymes), SPS and expansin (cell wall loosening protein).

Partial-length cDNA clones have been obtained for all these genes using these primers in banana. Fifteen ESTs have also been generated from fruit cDNA library of banana variety Mysore Poovan (Table 3).
Table 3. Banana ESTs putatively identified by the BLAST(n) database search

<table>
<thead>
<tr>
<th>Putative identification</th>
<th>Organism</th>
<th>EST size (bp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>integral membrane protein</td>
<td><em>Hordeum vulgare</em></td>
<td>590</td>
</tr>
<tr>
<td>Sec1 3p</td>
<td><em>Oryza sativa</em></td>
<td>590</td>
</tr>
<tr>
<td>transcriptional activator (b1) gene</td>
<td><em>Zea mays</em></td>
<td>372</td>
</tr>
<tr>
<td>ACC synthase gene</td>
<td><em>Musa acuminata</em></td>
<td>423</td>
</tr>
<tr>
<td>Peroxidase</td>
<td><em>Gossypium hirsutum</em></td>
<td>306</td>
</tr>
<tr>
<td>Amyrin synthase</td>
<td><em>Pisum sativum</em></td>
<td>510</td>
</tr>
<tr>
<td>Pdi 23 gene for PDI like protein</td>
<td><em>Arabidopsis thaliana</em></td>
<td>623</td>
</tr>
<tr>
<td>Kat A gene for catalase</td>
<td><em>Cajanus jejuni</em></td>
<td>623</td>
</tr>
<tr>
<td>Mitochondrial ATP synthase β subunit</td>
<td><em>Arabidopsis thaliana</em></td>
<td>357</td>
</tr>
<tr>
<td>Pectate lyase</td>
<td><em>Musa acuminata</em></td>
<td>445</td>
</tr>
<tr>
<td>Translation initiation factor (tif3 gene)</td>
<td><em>Viscum album</em></td>
<td>423</td>
</tr>
<tr>
<td>Putative MADS-box protein</td>
<td><em>Saururus chinensis</em></td>
<td>100</td>
</tr>
<tr>
<td>Chloroplast Tic 62 protein</td>
<td><em>Pisum sativum</em></td>
<td>510</td>
</tr>
<tr>
<td>18s small subunit ribosomal RNA gene</td>
<td><em>Triticum aestivum</em></td>
<td>447</td>
</tr>
<tr>
<td>polygalacturonase</td>
<td><em>Lycopersicon esculentum</em></td>
<td>544</td>
</tr>
</tbody>
</table>

Genes and partial cDNA clones isolated from banana

Banana varieties: Ney Poovan and Robusta
Full length genes: ACC oxidase and ACC synthase
Partial cDNA clones: PG, β-galactosidase, expansin and SPC

Generation of ESTs from banana cv. Mysore Poovan

Expression of β-galactosidase and ACC oxidase were studied in ripening banana fruits. While β-galactosidase was expressed in all stages of ripening, ACC oxidase was expressed only during the initial stages of ripening.

Full-length genes of SPS, ACC oxidase, ACC synthase and PG have been isolated from banana var. Robusta and Ney Poovan through RACE-PCR. Both 5’ and 3’ RACE-PCR products obtained were cloned and sequenced. Complete sequence of ACC oxidase gene from banana varieties Robusta and Ney Poovan has been determined. The full-length sequences of ACC oxidase gene isolated from banana cv. Robusta and Ney Poovan have been registered in Gene Bank of NCBI and the accession numbers were obtained.
Trainings conducted

Training on techniques in gene cloning, sequencing and plant transformation – a 10-day training programme was conducted in November 2003 for scientists of ICAR and teachers of SAUs. A hands-on gene isolation from banana fruit tissue was included in the activities.

Capacity building activities

To initiate work on banana improvement through genetic engineering, the scientists were trained in the following:

- Dr Subbaraya Uma was trained in “Banana Improvement Techniques through Agrobacterium-mediated Transformation” at KUL, Belgium by Dr Serge and Dr Lassloesagi with Dr Swennen as her promoter.
- Mrs M.S. Saraswathi was trained on “Mutant germplasm characterization using molecular markers” at International Atomic Energy Agency Vienna by Dr Stephen Nielen.

NRCB-organized programmes

Under an FAO-funded programme, Dr S. Uma and Dr R. Selvarajan were nominated as national consultants and undertook various training programmes for farmers, enterpreneurs and tissue-culture industries. Awareness was advocated on the use of virus-free tissue-culture planting materials with the assistance from state governments. Training on recognition of somaclonal variants in early stages and identification of viral diseases was imparted. These were also extended to more than 500 farmers, 100 trainers and 25 tissue-culture industries.

As a part of the programme, 12 farmers and 4 enterpreneurs were provided with the opportunities to attend the International Congress on Musa themed “Harnessing research to improve livelihoods” in Penang, Malaysia in July 2004.

Collection and conservation

Exploration and collection is one of the mandates of NRCB. Continuous efforts are made to explore, collect, characterize and evaluate Musa germplasms. In this endeavor, 68 wild and local cultivars were collected from North-Eastern states and Andaman, and Nicobar islands where Musa is supposed to have originated. This includes 16 pure balbisiana (BB). Four new Musa species have also been identified.
Network for the evaluation of global hybrids network in India

Work on evaluation of global hybrids is being conducted at the five SAU’s under various agro-climatic zones:

- Kerala Agricultural University, Thrissur, Kerala
- Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu
- Bidan Chandra Krishi Vidyalaya Agricultural University, West Bengal.
- ANG Ranga Agricultural University, Andhra Pradesh.
- Rajendra Agricultural University, Pusa, Bihar.

Apart from SAU’s, materials have also been supplied to three progressive farmers in Tamil Nadu where intensive evaluation is being carried out.

These trials were conducted at agricultural universities under AICRP (TF) and the results were as follows (Tables 4, 5, 6, 7, 8 and 9):

Table 4. Yield parameters and reaction to leaf spot disease of accessions planted in NRCB, Trichy.

<table>
<thead>
<tr>
<th>Accession name</th>
<th>Crop duration (days)</th>
<th>Bunch weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-01</td>
<td>342.1</td>
<td>16.4</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>366.3</td>
<td>21.6</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>370.2</td>
<td>17.2</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>385.9</td>
<td>20.6</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>453.5</td>
<td>18.5</td>
</tr>
<tr>
<td>PA-03-22</td>
<td>383.0</td>
<td>8.6</td>
</tr>
<tr>
<td>PV-03-44</td>
<td>354.2</td>
<td>9.4</td>
</tr>
</tbody>
</table>
Table 5. Yield parameters and reaction to leaf spot disease of accessions planted at the Banana Research Station, Kannara.

<table>
<thead>
<tr>
<th>Hybrids</th>
<th>Bunch weight (kg)</th>
<th>No. of hands</th>
<th>No. of fingers</th>
<th>Duration (days)</th>
<th>Reaction to leaf spot</th>
<th>Infection Index</th>
<th>YLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH – 3640</td>
<td>25.0</td>
<td>8.0</td>
<td>120</td>
<td>312</td>
<td>1.19</td>
<td>16.0</td>
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<tr>
<td>SH – 3436-6</td>
<td>18.0</td>
<td>10.0</td>
<td>150</td>
<td>338</td>
<td>13.1</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>TMB 5295-1</td>
<td>23.0</td>
<td>7.0</td>
<td>91</td>
<td>316</td>
<td>0</td>
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<tr>
<td>TMB x 1378</td>
<td>17.0</td>
<td>9.0</td>
<td>135</td>
<td>363</td>
<td>2.19</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>FHIA – 17</td>
<td>23.5</td>
<td>10.5</td>
<td>166</td>
<td>346</td>
<td>15.2</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>FHIA – 18</td>
<td>15.0</td>
<td>9.0</td>
<td>130</td>
<td>335</td>
<td>0</td>
<td>15.0</td>
<td></td>
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<tr>
<td>FHIA – 25</td>
<td>35.0</td>
<td>14.0</td>
<td>175</td>
<td>357</td>
<td>0.56</td>
<td>15.0</td>
<td></td>
</tr>
<tr>
<td>FHIA – 21</td>
<td>19.5</td>
<td>7.0</td>
<td>110</td>
<td>339</td>
<td>0</td>
<td>11.0</td>
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</tr>
<tr>
<td>CRPB – 39</td>
<td>16.0</td>
<td>7.5</td>
<td>108</td>
<td>350</td>
<td>0</td>
<td>12.0</td>
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<tr>
<td>Williams</td>
<td>15.5</td>
<td>9.0</td>
<td>135</td>
<td>340</td>
<td>18.6</td>
<td>9.0</td>
<td></td>
</tr>
</tbody>
</table>

*YLS: youngest leaf spotted

Table 6. Performance of yield parameters in fusarium wilt sick plot at ANG Ranga Agricultural University, Andhra Pradesh.

<table>
<thead>
<tr>
<th>Accession</th>
<th>Genome</th>
<th>Bunch weight (kg)</th>
<th>No. of hands/bunch</th>
<th>No. of fingers/bunch</th>
<th>Average weight of finger (g)</th>
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<tbody>
<tr>
<td>FHIA- 01</td>
<td>AAAB</td>
<td>13.75</td>
<td>9.3</td>
<td>122.9</td>
<td>112.0</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>AABB</td>
<td>21.95</td>
<td>8.6</td>
<td>140.2</td>
<td>174.4</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>AAAA</td>
<td>22.50</td>
<td>9.4</td>
<td>130.9</td>
<td>173.9</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>AAAA</td>
<td>22.55</td>
<td>9.7</td>
<td>143.2</td>
<td>160.3</td>
</tr>
<tr>
<td>PV-03-44</td>
<td>AAAB</td>
<td>4.20</td>
<td>6.0</td>
<td>70.0</td>
<td>60.5</td>
</tr>
<tr>
<td>PA-03-22</td>
<td>AAAB</td>
<td>3.45</td>
<td>6.8</td>
<td>96.8</td>
<td>36.3</td>
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<tr>
<td>GCTC-119</td>
<td>AAA</td>
<td>8.15</td>
<td>5.2</td>
<td>69.2</td>
<td>120.5</td>
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<tr>
<td>GCTC-215</td>
<td>AAA</td>
<td>11.10</td>
<td>7.1</td>
<td>97.1</td>
<td>111.7</td>
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</table>
Table 7. Yield characters of FHIA hybrids in plant crop (PC) and first ratoon crop (R1) at Rajendra Agricultural University, Pusa, Bihar.

<table>
<thead>
<tr>
<th>Hybrids / clones</th>
<th>Days to flower</th>
<th>No. of finger / bunch (m)</th>
<th>Bunch weight (kg)</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PC</td>
<td>R1</td>
<td>PC</td>
<td>R1</td>
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<tr>
<td>FHIA-01</td>
<td>399.2</td>
<td>378.3</td>
<td>160.5</td>
<td>200.3</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>405.7</td>
<td>390.2</td>
<td>163.6</td>
<td>190.5</td>
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<tr>
<td>FHIA-17</td>
<td>402.4</td>
<td>375.6</td>
<td>136.2</td>
<td>179.5</td>
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<tr>
<td>FHIA-23</td>
<td>405.2</td>
<td>388.7</td>
<td>148.7</td>
<td>165.6</td>
</tr>
<tr>
<td>‘Saba’</td>
<td>410.2</td>
<td>392.3</td>
<td>152.8</td>
<td>141.5</td>
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</table>

Table 8. Performance of FHIA hybrids at Tamil Nadu Agricultural University, Coimbatore.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Bunch weight (kg)</th>
<th>Finger weight (g)</th>
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</thead>
<tbody>
<tr>
<td>FHIA-03</td>
<td>23.00</td>
<td>80.00</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>24.00</td>
<td>130.00</td>
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</table>

Table 9. Evaluation of FHIA hybrids against sigatoka leaf spot diseases of banana at RCC, Arabhavi.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Sigatoka leaf spot index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6 months</td>
</tr>
<tr>
<td>FHIA-01</td>
<td>7.24</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>8.89</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>14.28</td>
</tr>
</tbody>
</table>
These trials were conducted at agricultural universities under AICRP

**List of approved ongoing projects**

1. Management of genetic resources of banana (S. Uma)
2. Crop improvement of banana through conventional breeding (S. Sathiamoorthy)
3. Crop improvement through non conventional approaches (S. Uma, S. Sathiamoorthy and M.S. Saraswathi)
4. Standardization of agrotechniques for banana production and productivity (S.D. Pandey)
5. Standardization of technology for organic banana production (M.M. Mustaffa)
6. Standardization of nutritional requirements of banana using soluble fertilizers (V. Kumar)
7. Integrated nutrient management in banana (K.J. Jeyabaskaran)
8. Studies on micronutrients in banana (K.J. Jeyabaskaran)
9. Studies on handling, storage and processing of banana (C.K. Narayana)
10. Insect pest management in banana (B. Padmanaban)
11. Studies on banana nematodes and their management (P. Sundararaju)
12. Investigation on fungal and bacterial diseases of banana and their management (R. Thangavelu)
13. Studies on viral diseases of banana and their management (R. Selvarajan)

**Other points to be discussed**

1. Intervene in the process of *Musa* germplasm deposition with ITC collected under INIBAP project (letter enclosed for information).
2. Strengthen the Asian Breeding Programme through collaboration with other global breeding centers.
3. Facilitate more interaction among Asian scientists working on banana and plantains.
4. Provide information to funding agents where projects from Asia can be proposed in collaboration with other developed laboratories.

**Area of collaboration with BAPNET-member countries**

Introduction and exchange of banana germplasm resistant to fusarium wilt.
Banana R&D in Indonesia: Updates and highlights

Suyamto*, I. Djatnika and A. Sutanto

Banana is the most important and widely planted fruit in Indonesia, with a planting area of 74,751 ha and production totaling 4.5 million tonnes (Anonymous 2003). Banana has the highest production rate among all fruit crops. Major banana production areas are found in Java (54%), contributing to 68% of national banana production, while large potential lands are available in Sumatera (over 1 million ha), Kalimantan, Sulawesi and Papua (over 3 million ha) (Djohar et al. 1999).

Commonly, banana is planted as a backyard crop or mixed with other crops such as cassava, coconut and other perennial fruit trees with minimum input management. In some areas, banana is planted as a smallholding system (≤ 1 ha). The varieties planted depend on the local commercial varieties of each region. Pisang Barangan (AAA) is very popular in North Sumatera, Nusa Tenggara Timur and Papua, while Ambon Kuning (AAA) and Tanduk (AAB) are very common in Java. Raja Sereh (AAB) and Ambon Hijau (AAA) are more expensive than Barangan in West Sumatera. Berlin (AA) is a commercial variety in Lampung and West Java, while Kepok (ABB) and Raja Bulu (AAB) are popular cooking bananas in Indonesia. Time of harvest also varies among regions so that bananas are always available throughout the year.

Production constraints

Currently, the major limiting factors of banana production are banana wilt, caused by Fusarium oxysporum f.sp. cubense (Foc), bacterial blood disease (BBD), and Ralstonia solanacearum, damaging banana plantations nearly throughout almost all provinces in Indonesia.

Fusarium wilt mostly known as Panama disease is one of the most damaging diseases to the growers worldwide. In Lampung banana growing areas, fusarium wilt and blood disease caused economic losses of about US$6.8 million during the 1993-1994 harvest season (Nurhadi et al. 1994). A commercial banana farm, located in Halmahera, was predicted to have a huge loss of Rp30 billion (US$8.6 million) each time of harvest season since 1995. Approximately, 1000 hectares of this plantation have already been affected by fusarium wilt.

*Director, ICHORD/AARD, Jakarta, Indonesia.
Hutagalung (2002) stated that if the total cultivated area of banana farms is more than 1 ha, the problem of disease becomes very important. It will reduce the quantity and quality of yield. In Lampung, fusarium wilt causes economic losses of 10-65%. For the period 1973-2002, the presence of the disease caused a decline in banana production of 60-70%, and a significant economic damage amounting to Rp54.5-63.6 billion (US$9.1-10.6 million) or Rp1.88-2.19 billion (US$0.3-0.4 million) per annum. The commercial cultivars that are susceptible to fusarium wilt are Barangan (AAA), Raja Serai (Silk, AAB) and Ambon Kuning (AAA).

In Indonesia, bacterial wilt ranked first in the disease-priority list provided by the Asia Pacific Network (Valmayor 1989). The affected plants are varied. In South Sulawesi, the incidence was estimated at 70-80% (Roesmiyanto and Hutagalung 1989); and it was at 27-36% in West Java (Subhan 1988 cited in Muharam and Subijanto 1991). Pisang Kepok (Saba, ABB/BBB) is very susceptible to bacterial wilt.

R&D activities in Indonesia

Status of Musa germplasm management

The Indonesian Fruit Research Institute (IFRI) has collected 200 accessions of Musaceae from Sumatera, Java, Maluku Islands and Papua. However, some are duplicates or synonyms. The collections are maintained *ex situ* in the field, *in vitro* in the laboratory and *in vivo* in the screenhouse. Due to limited space in the screenhouse, only ITC accessions are maintained in the screenhouse. About 85% of the accessions have been characterized and entered into MGIS. Another collection site is in Berastagi experimental field. Thirty-five accessions have been collected in this germplasm field (21 accessions from ITC and 14 accessions of local varieties). The accessions from ITC are also maintained at the Bogor Agriculture University, West Java. This university carries out banana collecting missions and banana molecular marker development, however, no information on the total number of accessions is available. Another well managed banana germplasm collection is in Yogyakarta. This collection field is managed by the regional government of Yogyakarta. Over 150 accessions are conserved *ex situ*. 
**Banana breeding programmes**

Research in breeding is mainly confined to developing disease-resistant varieties. Both fusarium wilt and bacterial wilt are serious in most parts of Indonesia. The Indonesian programme’s main objective is the breeding of wilt-resistant banana varieties. This is implemented by the IFRI.

Conventional hybridization of banana has started in 1999. The first approach was the identification of resistant sources of male parents. For this, five accessions, namely, Kole (AA), Klutuk (BB), Jaran (*M. acuminata* spp. *burmanica*), BKT-11 (AAw) and Calcutta-4 (AAw) were obtained. These male parents were crossed with commercial varieties (female parents). The hybrid seeds were obtained when Calcutta-4 crossed with Kepok Kuning (ABB), Raja Siem (ABB) and Ketan (AAB). The hybrid plants are now being evaluated in the field.

**National Repository, Multiplication and Distribution Centre**

On 11 May 2001, the Central Research Institute for Horticulture (presently known as the Indonesian Center for Horticulture Research and Development-ICHORD) entered into an agreement for the establishment of the activities in relation to the maintenance and distribution of *Musa* germplasms through LOA/INIB 2001/26. The LOA was signed between the director of ICHORD Dr. A. Dimyati, representing the government of Indonesia, and INIBAP Regional Coordinator Dr. A. Molina, representing INIBAP. This agreement was then followed by another LOA signed on 6 July 2001 (LOA/INIB 2001/22) regarding germplasm evaluation in the framework of the International *Musa* Testing Programme (IMTP). Table 1 shows the list of all accessions received by ICHORD from INIBAP ITC. These materials were later sent to the tissue-culture laboratory of Indonesian Ornamental Crop Research Institute, Cipanas, West Java. All the accessions have been multiplied and sent to IFRI and Bogor Agriculture University, West Java. IFRI was chosen by ICHORD as a national repository multiplication and distribution centre of ITC and other banana/plantain accessions in Indonesia.
Further multiplications of ITC accessions were done in the tissue culture laboratory of IFRI in Solok. Moreover, local varieties and Papua accessions were multiplied in the same laboratory. Some plantlets of ITC accessions were acclimatized on the seedbeds and transferred to plastic polybags. Until February 2003, from the 21 accessions sent by ITC, only 14 accessions were used for the International Musa Testing Programme-Phase III (IMTP-III) in Aripan experimental field. This is because when the project started, planting materials were limited. Besides the accessions from ITC, 10 local cultivars were also tested. Further acclimatization was done for the preparation of IMTP-III materials in North Sumatera. Furthermore, on March 2003, those materials were brought to Berastagi experimental station, North Sumatera.

**International Musa Testing Programme**

Under the coordination of ICHORD, IFRI carried out the International Musa Testing Programme-Phase III (IMTP-III) in 2003. This project has been carried out in West Sumatera and North Sumatera. The results showed that some tetraploid accessions indicated tolerance to fusarium wilt. These are: SH-3640, SH-3436-9, CRBP-39, FHIA-25, FHIA-17 and TMBX 1378. Aside from resistance to the diseases, postharvest characteristics were also evaluated. SH-3640 is suitable as dessert banana with medium firmness, medium peduncle strength and sweet predominant taste, while CRBP-39 is suitable for cooking. The highest bunch weight was obtained by FHIA-25 (45 kg), but the taste and texture were not suitable for dessert and cooking. This accession may be processed as banana flour. Currently, SH-3640, GCTCV-119, CRBP-39 and two local varieties are being multiplied *in vitro* for field trial and distribution to farmers.
The results of IMTP-III in Berastagi experimental field were different than in Aripan. This may be due to the elevation of Berastagi which is 1430 m asl (high land). No fusarium wilt symptoms were observed in the accessions. On the other hand, symptoms of sigatoka leaf spot were ranked from 4.7% to 90%. The recommended variety for sigatoka resistance was ‘Yangambi Km5’ which produced 90% disease severity (DS) of sigatoka. ‘Cachaco,’ FHIA-03 and FHIA-02 produced 73.3%, 78.7% and 41.0%, respectively.

**Control of banana pests and diseases through IPM strategies**

The use of living organisms to reduce the impact of pests is a concept of classical biological control. The effectiveness of pathogen control can be increased by the augmentation of antagonistic microbes population. *Pseudomonas fluorescens* strain MR 96 and *Gliocladium* sp. are antagonistic microbes of *Fusarium oxysporum*. The infected plants were significantly reduced (68.5%) when the suspension of *Pseudomonas fluorescens* strain MR 96 was poured to the soil surrounding banana (5-month-old) rhizosphere (Djatnika *et al.* 2003). The use of SH modification (SHM) medium alone or in combination with *Pseudomonas fluorescens* strain MR 96 suppressed Foc. The symptoms of Foc were decreased up to 46.5% when SHM 1% was mixed with medium, while SHM 2% could reduce 60.9% of the symptoms. The combination of SHM 1% and *Pseudomonas fluorescens* strain MR 96 can reduce 73.4% of Foc symptoms.

Currently, IFRI is preparing a standard method for production and distribution of banana planting materials. Mother-plant selection, virus indexing, *in vitro* multiplication and distribution system of the plants are included in this method. The certification of planting materials is issued by the Seed Monitoring and Certification Institute.

**Capacity building**

Under the sponsorship of INIBAP, some researchers of IFRI attended relevant trainings, workshops and seminar. These trainings, including the researchers’ name, are as follows:

1. Iwan Sukmayadi, International Training Course on Tissue Culture Techniques of Banana, 9-14 December 2002. Taiwan Banana Research Institute, Taiwan.


The Indonesian Fruit Research Institute collaborated with other institutions to hold the following workshops:
1. Workshop on Banana Wilt Disease, 22 October 2002 in Padang, West Sumatera.

A National Workshop on Banana Wilt Disease will be organized by ICHORD in December 2004.

**National programmes**

For the next five years starting from 2005, research will be focused on the first three priority fruits, namely banana, citrus and mango. The second priority fruits will be mangosteen, durian and other fruits based on partner demand and government requirement.

Banana diseases are still the national constraint to banana production. There are two main research activities regarding banana diseases to be accomplished by ICHORD through IFRI in 2005. The first activity is breeding for national wilt disease resistant variety, including wilt disease and black sigatoka control through the integrated pest management; and the second, the dissemination of banana production system to the farmers through on-farm research. The global programmes of banana research are described on the Roadmap of R&D on Banana (Figure 1). Other banana research programmes are carried out by universities but with focus on the main programme which is the control of banana viruses and banana production system. There are coordination and collaboration between IFRI and Bogor Agriculture University on banana research programme. This coordination is required in order to avoid the overlapping of different programmes.
References


Figure 1. Roadmap of R&D on banana.

ROADMAP OF RESEARCH AND DEVELOPMENT ON BANANA

<table>
<thead>
<tr>
<th>CURRENTLY CONDITION 2004</th>
<th>RESEARCH AND DEVELOPMENT STRATEGY</th>
<th>OBJECTIVES (2005-2009)</th>
<th>IDEAL CONDITION</th>
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<td>ON-FARM</td>
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<tr>
<td>High Quality of Planting Materials</td>
<td>Conventional breeding, selection</td>
<td>Wilt resistant and commercial varieties, Crop management efficiency, Nutrition, water and IPM</td>
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<td>Production Management</td>
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<tr>
<td>OFF-FARM</td>
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<td>Added Value Improvement</td>
<td>Development of downstream industry</td>
<td>The improvement of efficiency technology of downstream industry</td>
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<td>Development of Infrastructures</td>
<td>International Collaboration</td>
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<td>Marketing Development</td>
<td>Marketing Efficiency Development</td>
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<td>Development of Production System</td>
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<td>ONE OF MAIN BANANA PRODUCERS AND EXPORTERS IN SOUTH EAST ASIA</td>
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</table>

CURRENTLY AGROBUSINESS PROFILE
Low Productivity
Low Quality

HIGH INCOME
HIGH PRODUCTIVITY
COMPETITIVE

IDEAL CONDITION
ONE OF MAIN BANANA PRODUCERS AND EXPORTERS IN SOUTH EAST ASIA
Enhancing the Malaysian banana industry: R&D

Nik Masdek Hassan*

Abstract

Banana as one of the premier and popular fruits in Malaysia covers more than 11% of the total fruit area. The annual production is about 180,000 tonnes, with more than 15% of the yearly production and a balance of trade of more than RM30 million (US$8 million). Plans are underway to more than double the production figures. This can be achieved by increasing the acreage under cultivation, increasing the yield per unit area and enhancing the production technology. Technological advancement through research and development are being conducted to alleviate production constraints and increase productivity. Research efforts are concentrated towards improvement of existing cultivars, improvement of agronomic practices and of utmost importance—the management of pest and diseases. Cultivar improvement activities involve selection of endogenous and introduced cultivars, induced mutation, somaclonal variation and biotechnological transformation. Mass-propagation techniques of several local cultivars were studied in relation to production of planting materials or as a system in genetic transformation. The ravages of pest and diseases are a constant threat to the banana industry. Research efforts are concentrated towards managing the threat of fusarium wilt and foliar diseases as well as viruses, insects and nematodes. Effort in managing fusarium wilt, the most dangerous threat to the banana industry worldwide, is being intensified. Resistant genes from the wild bananas are being evaluated and characterized and the host-pathogen relationship is being evaluated. Biological control of fusarium wilt is being pursued through the use of bacterial and fungal endophytes, plant growth promoting rhizobacteria and through evaluating microbes from suppressive soils.

Introduction

The Third Malaysian National Agricultural Policy, preceded by the first and second national agricultural policies of the 1980s and 1990s, was launched in 1999 to provide a pathway for further development.

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of agriculture up to the year 2010. This present policy also stated that fruit cultivation and production will be accorded top priority status and contributed to the gross income of the country.

Banana is one of the important fruit crops cultivated in Malaysia. It is ranked second in terms of production area and fourth in export revenue based on the balance of trade figures. This crop will remain as an important industry, emphasis given to this crop in addition to the other fruit types listed under the National Agricultural Policy.

The acreage under banana has stabilized at about 34,000 ha over the past several years with an annual production of about 180,000 metric tonnes valued at about RM90 million (US$24 million). Fifteen percent of the banana produced are exported valued at more than RM30 million (US$8 million). Efforts are being undertaken to more than double the production figures in the next 5 or more years. It is envisaged that this can be achieved through increasing the production areas, increasing the yield per unit area and enhancing the production technology. Technological advancement through intensified research and development activities will ensure sustainable growth in the industry. The aim of this paper is to look at the various research activities being carried out to bring the industry to the targeted production level.

### Banana research activities in Malaysia

**Musa germplasm**

The germplasm collection has more than 200 accessions representing the collections from Malaysia and neighbouring countries. Collection activities are somewhat ongoing and become a continuous exercise. Further collections will concentrate on specific cultivars and for a specific interest. Presently, one of our researchers is making a survey and collection of the cooking bananas, such as Pisang Abu, P. Tandok and P. Nipah, and identifying the variations in the cultivars, mapping out the distributions and looking at the suitability and popularity of the various cultivars in banana chips production.

Collections were also conducted on Pisang Raja, aimed at finding improved yield, quality and resistance or tolerance to diseases especially fusarium wilt. Pisang Rastali was also collected from various locations, especially those that can sustain several crop cycles without being infected by fusarium wilt. These collections were then further tested in naturally infested plots.

In the vast collection of germplasm, the existence of diversity and the naming based on the traditional and localized nature have imposed a lot of confusion and differences of opinion. The conventional
characterization techniques also have limitations to address the various levels of diversity. Thus, research is underway to characterize the collections in the banana germplasm based on the recent advances made in molecular biology. DNA sequencing and DNA markers will be used to characterize *Musa* germplasm and detect the variation between and within the cultivars or species. All the modern and advance methods will be used to fingerprint the accessions.

**Plant regeneration and mass propagation of local cultivars**

Traditionally, plant regeneration and mass propagation of bananas have been done through the use of meristem cultures. Now researchers are experimenting and using explants of male inflorescence. From these immature male flowers, embryogenic cell suspensions were developed. The advantage of using explants of male inflorescence in mass propagation is the reduction in the risk of viral contamination. It also seems to have a lower rate of somaclonal variation. Embryogenic cell suspension can be used in gene transformation and plant regeneration. Efforts are underway to mass propagate P. Berangan, P. Mas, P. Tandok, P. Jari Buaya and P. Rastali as well as the wild types using embryogenic cell cultures.

**Resistance to fusarium wilt**

Fusarium wilt of banana or Panama disease caused by *Fusarium oxysporum* f. sp. *cubense* is the most important disease of banana in Malaysia and causes huge economic losses to the banana industry. Until now, there are no effective methods available to control the disease. Thus, numerous research efforts are concentrated towards understanding the nature of the disease and looking for possible methods of controlling the disease.

**Resistance to Foc race 4 – *Musa acuminata ssp. malaccensis***

Screening of suckers of *Musa acuminata ssp. malaccensis* in Foc race 4 infested field showed the resistance of this wild type. Further screening of the seedling population showed variation in resistance. This may be due to outcrossing that occurs among the population. Analysis of the screened population showed a 3:1 resistance:susceptible ratio indicating that resistance is controlled by a single dominant gene. Further crosses and biotechnological screening and evaluation were made.
Microarray analysis of gene expression

The objective of this study was to compare gene expression profiles of P. Rastali cultivar Mutiara (tolerant to fusarium wilt) and P. Rastali (susceptible to fusarium wilt) using microarray technology. This is achieved through construction of the cDNA microarray of the two cultivars. Hopefully, this study will provide answers on the genetic mechanism of disease tolerance/resistance and help develop banana varieties resistant to fusarium wilt.

Early detection of fusarium wilt

Early detection of fusarium wilt through the use of markers is crucial for detection in the field as well as for the detection of the transformation of resistant genes into susceptible varieties. A semi-quantitative bioassay for early and rapid detection of susceptibility tests against fusarium wilt was conducted. The effect of inoculum density on infection was determined. The biochemical parameters such as hydrogen peroxide and other enzymes such as phenylalanine ammonia lyase, chitinase, glucanase, peroxidase and polyphenol oxidase in infected roots will be determined and the levels related to tolerance or susceptibility to fusarium wilt will be evaluated.

Transformation of bananas

Biotechnological improvement of bananas through transformation with genes associated with various characteristics are also being carried out to find a workable and efficient protocol. It is aimed at improving the agronomic characteristics of specific cultivars of banana or at incorporating genes conferring resistance to diseases especially fusarium wilt.

Biological control of fusarium wilt

In an attempt to find a solution to fusarium wilt, biological control methods are being evaluated and attempted as part of the integrated control measures. Various biological control strategies are being evaluated such as endophytes, plant growth promoting rhizobacteria as well as other microbes and the mechanism of suppressive soils.

Endophytes to suppress fusarium wilt

Endophytic microorganisms from wild bananas are being investigated as a potential bio-control agent against *Fusarium oxysporum* f. sp. *cubense* Race 4. Endophytes are natural internal-tissue colonizers and are advantageous in providing competition for nutrients and space,
provide buffer from environmental stress and trigger plant defense mechanism; thus, improve and enhance plant growth. Several isolates showed positive reaction such as suppressing fusarium wilt development, no severe inhibition of plant growth and triggering host resistance. These isolates were selected and can be introduced into the host system by simple inoculation methods.

**Plant-growth-promoting rhizobacteria**

Plant-growth-promoting rhizobacteria are root and rhizosphere-inhabiting bacteria with ability to increase plant growth by a variety of mechanism. Among the benefits of these groups of bacteria are: the ability to exert antifungal activities and to be useful for bio-control of fungi, ability to colonize plant root and stimulate growth of host plant, ability to stimulate root development and increase absorption of water and plant nutrients in bananas, and the ability to enhance plant nutrient uptake and act as biocontrol agent for plant disease.

Bacterial isolate, *Bacillus sphaericus*, was shown to inhibit growth of Foc race 4 *in vitro* and disrupt hyphal growth of Foc. This bacterial isolate will also enhance the growth of banana and reduce the disease severity index (based on vascular discoloration) of seedlings.

**Other bio-control research activities**

Researchers have also identified an actinomycetes *Streptomyces violaceusniger* that produced extracellular antifungal metabolites that strongly inhibit spore germination and hyphal development of Foc race 4 *in vitro*. This actinomycetes was also shown to reduce disease severity in plantlets inoculated with the Foc race 4.

The occurrence of soil suppressive to the development of fusarium wilt was also being evaluated. From a survey, certain areas were found to be free from infection by fusarium wilt. Results showed that the disease was more severe in sandy soils compared with clay and riverine alluvium soil. The suppressive soils were characterized with high pH of close to seven, and have higher levels of calcium, magnesium and iron. Several microorganisms have been isolated and were involved in suppressive properties.

**IMTP-III in Malaysia**

Malaysia is also a participant in the IMTP-Phase III project for the establishment, evaluation and promotion of improved varieties of banana. A demonstration cum research plot was established at MARDI Headquarters in Serdang and other plots will be established at other
locations. The objective of this project is to evaluate the introduced varieties in relation to yield, fruit quality, reaction to diseases, pests and other agronomic characters. Hopefully, these studies will identify varieties that are suitable and can be promoted to the farmers.

Twenty improved and superior varieties of banana were introduced from the *Musa* International Transit Centre through the BAPNET office and the plantlets propagated in the laboratory. In addition, 12 local selections were included as check varieties. Planting was carried out on a naturally fusarium-infested site in a completely randomized design with 20 replicates. The plots will be evaluated for their reactions to fusarium wilt, sigatoka diseases and nematodes.

Initial results of fusarium wilt infection after one crop cycle are as shown in Table 1. The various hybrids and somaclones showed different levels of infection (0-45%) to fusarium wilt. FHIA-18 and FHIA-25 showed good resistance to the disease. The somaclones (GCTCV-106, GCTCV-215 and GCTCV-247) have 45%, 35% and 25% mortality, respectively. The other hybrids showed only 5-15% mortality rates. The check varieties cv Rose and ‘Pisang Jari Buaya’ remained resistant without any incidence of mortality. The susceptible ‘Gros Michel’ and Cavendish-‘Williams’ were badly affected by the disease but Bluggoe-Cachaco had only 10% mortality. The local cultivars were badly infected except ‘P. Tanduk’ and ‘P. Abu Nipah’ with only 10% mortality.

Evaluation of the sigatoka diseases based on the infection index showed that the cultivars BITA-2 and ‘Pisang Jari Buaya’ remained free from the disease (Table 2).

The resistant check ‘Yangambi km5’ as expected remained free from the disease. ‘Calcutta 4’ also shows a resistant reaction to sigatoka diseases.

**Other activities**

**International banana congress**

This congress was successfully held in July 2004 in Penang, Malaysia and is the realization of the effort of INIBAP, MARDI, BAPNET, IPGRI Malaysia and other universities, research institutions and entrepreneurs in Malaysia. Parallel to this congress, the Fourth International Symposium on the Molecular and Cellular Biology of Banana was held. The congress has attracted about 300 participants from more than 40 countries representing all the continents of the world, and the participants shared their findings through 94 oral presentations and
Table 1. Initial reaction of banana cultivars (IMTP III) to fusarium wilt based on natural infection and external symptoms.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>No. of plants without symptoms</th>
<th>No. of plants with yellowing foliage</th>
<th>No. of plants with pseudostem splitting</th>
<th>No. of plants that died</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA18</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-21</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-25</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SH-3640</td>
<td>16</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>GCTCV-106</td>
<td>11</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>GCTCV-215</td>
<td>13</td>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>GCTCV-247</td>
<td>15</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>CRBP-39</td>
<td>18</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>BITA-3</td>
<td>16</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>BITA-2</td>
<td>17</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>‘Gros Michel’</td>
<td>4</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>‘Bluggoe-Cachaco’</td>
<td>16</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Cavendish-‘Williams’</td>
<td>11</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>‘Cv Rose’</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Yangambi km 5’</td>
<td>19</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>‘Calcutta 4’</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘P. Ceylan’</td>
<td>19</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>‘P. Berlin’</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Gran Enano’</td>
<td>12</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>‘P. Jari Buaya’</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Novaria’</td>
<td>10</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>‘Montel’</td>
<td>9</td>
<td></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>‘P. Mas’</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>‘Rastali cv. Mutiara’</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>‘P. Nangka’</td>
<td>13</td>
<td></td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>‘P. Tanduk’</td>
<td>18</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>‘P. Raja’</td>
<td>5</td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>‘P. Abu Nipah’</td>
<td>18</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>‘P. Awak’</td>
<td>16</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>‘P. Berangan Intan’</td>
<td>6</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>‘P. Berangan Merah’</td>
<td>4</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>‘P. Berangan Kapar’</td>
<td>5</td>
<td></td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

more than 140 posters on topics ranging from genetic resources, production and cropping systems, plant protection, postharvest and processing.

**MGIS Workshop**

The *Musa* Germplasm Information System (MGIS) training workshop was held at MARDI Training Centre, Serdang on 15-19 December 2003. This training workshop was to provide curators of *Musa* germplasm collections in Asia with the expertise and tools in order to better manage information related to the accessions in their collections. This will also
facilitate the exchange of genetic resource information with other researchers and curators throughout the world. A total of 22 participants from 14 countries in this region participated in the week-long workshop.

Table 2. Preliminary results on the infection index (%) of sigatoka diseases of banana cultivars (IMTP III).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>At 6 months</th>
<th>At bunch emergence</th>
<th>At harvest</th>
</tr>
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<tbody>
<tr>
<td>FHIA18</td>
<td>0</td>
<td>1.7</td>
<td>16.7</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>0</td>
<td>1.9</td>
<td>45.5</td>
</tr>
<tr>
<td>FHIA-25</td>
<td>2.7</td>
<td>0</td>
<td>21.4</td>
</tr>
<tr>
<td>SH-3640</td>
<td>0</td>
<td>14.3</td>
<td>21</td>
</tr>
<tr>
<td>GCTCV-106</td>
<td>9.5</td>
<td>9.5</td>
<td>47.7</td>
</tr>
<tr>
<td>GCTCV-215</td>
<td>7.9</td>
<td>8.3</td>
<td>42.2</td>
</tr>
<tr>
<td>GCTCV-247</td>
<td>7.9</td>
<td>9.8</td>
<td>46.8</td>
</tr>
<tr>
<td>CRBP-39</td>
<td>0</td>
<td>0</td>
<td>4.2</td>
</tr>
<tr>
<td>BITA-3</td>
<td>0</td>
<td>0</td>
<td>11.1</td>
</tr>
<tr>
<td>BITA-2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>‘Gros Michel’</td>
<td>3.0</td>
<td>2.9</td>
<td>31.2</td>
</tr>
<tr>
<td>‘Bluggoe-Cachaco’</td>
<td>4.4</td>
<td>5.0</td>
<td>48.7</td>
</tr>
<tr>
<td>Cavendish-Williams’</td>
<td>8.5</td>
<td>8.5</td>
<td>59.7</td>
</tr>
<tr>
<td>‘Cv Rose’</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>‘Yangambi Km 5’</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>‘Calcutta 4’</td>
<td>0</td>
<td>0</td>
<td>29.6</td>
</tr>
<tr>
<td>‘P. Ceylan’</td>
<td>0</td>
<td>0</td>
<td>17.5</td>
</tr>
<tr>
<td>‘P. Berlin’</td>
<td>3</td>
<td>2.8</td>
<td>8.4</td>
</tr>
<tr>
<td>‘Gran Enano’</td>
<td>16.9</td>
<td>16.9</td>
<td>62.2</td>
</tr>
<tr>
<td>‘P. Jari Buaya’</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td>‘Novaria’</td>
<td>6.5</td>
<td>6.5</td>
<td>44.6</td>
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<td>‘Montel’</td>
<td>8.0</td>
<td>8.0</td>
<td>57.4</td>
</tr>
<tr>
<td>‘P. Mas’</td>
<td>0</td>
<td>0</td>
<td>8.3</td>
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<td>‘Rastali cv. Mutiara’</td>
<td>0</td>
<td>5.8</td>
<td>11.9</td>
</tr>
<tr>
<td>‘P. Nangka’</td>
<td>0</td>
<td>3.7</td>
<td>41</td>
</tr>
<tr>
<td>‘P. Tanduk’</td>
<td>2.3</td>
<td>5.1</td>
<td>24.2</td>
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<tr>
<td>‘P. Raja’</td>
<td>5.8</td>
<td>7.5</td>
<td>48.1</td>
</tr>
<tr>
<td>‘P. Abu Nipah’</td>
<td>3.8</td>
<td>4.4</td>
<td>16.7</td>
</tr>
<tr>
<td>‘P. Awak’</td>
<td>0</td>
<td>4.5</td>
<td>27.8</td>
</tr>
<tr>
<td>‘P. Berangan Intan’</td>
<td>0</td>
<td>4.5</td>
<td>41.7</td>
</tr>
<tr>
<td>‘P. Berangan Merah’</td>
<td>3</td>
<td>3.7</td>
<td>-</td>
</tr>
<tr>
<td>‘P. Berangan Kapar’</td>
<td>3.7</td>
<td>10.2</td>
<td>51.4</td>
</tr>
</tbody>
</table>
Current situation of banana R&D in Myanmar

Aye Tun*

Introduction
Myanmar is located between 9° 59' and 28° 31' N latitude and 92°10' and 101° 09' E longitude. The total area is 670 720 km² or 67 658 M ha of which about 9.67 M ha (14%) is currently cultivated. The agriculture sector is the most important as it contributes 35% of export earnings. Myanmar is home to several species of plants because of different agro-ecological zones. Among them, more than a hundred horticultural crops are grown in the various climatic conditions such as tropical and subtropical. From 2001 to 2002, the cultivated area for horticultural crops was more than 1 M ha.

The horticultural crops rank fifth in the agriculture sector. Therefore, the Ministry of Agriculture and Irrigation endeavours to boost the production of these crops through area expansion, introduction of improved varieties, technology transfer and market information to the growers.

Agro-climatic condition
Myanmar has tropical and sub-tropical climates with three general seasons, namely the rainy season (mid-May to mid-October), the dry cold season (mid-October to mid-February) and the hot season (mid-February to mid-May). The average annual rainfall varies over the country, ranging from 2540 mm to 5080 mm in the coastal and hilly regions, and from 762 to 1016 mm in the central dry zone. The temperature in the south differs a little from season to season. However, seasonal temperature variation of central plain lies in the magnitude of about 40°-43°C in the hot season and 10°-15°C in the cold season. In hilly regions, the average daily maximum is approximately 29°C and the minimum is 7°C.

Banana growing in Myanmar
In Myanmar, banana is one of the most important and common fruits. It can be grown throughout the country. According to 2002-2003 statistics, banana cultivated area was approximately 57 847 ha and production was 110.4 M bunches (552 051 t). All produced bananas

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are consumed locally.

Thirteen *Musa* species, including wild species are widely grown throughout the country. Among them, *Musa acuminata*, *M. cavendishii* and four varieties under *M. sapientum* are the most common varieties.

Home or backyard gardening is the common cultivation practice in Myanmar especially in the rural areas. Although commercial plantations can be found in only seven states and divisions, pests and diseases problem exist also in other areas. However, banana growers are not aware of these problems. Therefore, no control measures are being taken by farmers.

**Banana R&D activities**

The banana R&D activities are as follows:

- Germplasm collection of local cultivars and introduced varieties
- Varietal trials on introduced varieties
- Cultural practices
- Multiplication methods
- Postharvest handling technology

**Germplasm collection**

The Vegetable and Fruit Research and Development Center (VFRDC) in cooperation with the DAR (Department of Agriculture Research) and Yezin Agriculture University conducted evaluation studies on banana germplasm. In VFRDC, 32 local cultivars and 28 introduced varieties are maintained with which varietal and adaptability trials were conducted. The list of affected germplasm collection and results of evaluation on banana are shown in Tables 1 and 2.

The germplasm is maintained for conservation and for selection on pest and disease resistance/tolerance.

Likewise, Myanmar received from INIBAP ITC 23 cultivars, and their conditions were observed in VFRDC. Results are shown in Table 3.

One set of the 23 varieties was sent to DAR for field trials, while the remaining four sets were planted by VFRDC in the field and in pots in the screenhouse. Two plants of each cultivar were grown in the field and two plants the pots are placed in the screenhouse.

**Varietal trial and adaptability test**

The banana is essentially planted in tropical lowland. The varietal trial on local cultivars was conducted to get the fruit quality, yield, and
Table 1. Local cultivars, genotype and characteristics.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Genome group</th>
<th>Flower bud shape</th>
<th>Leaf tip</th>
<th>Fruit shape</th>
<th>Fruit peel color</th>
<th>TSS (Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red banana (Shwe Ni) Cavendish</td>
<td>AAA</td>
<td>ovoid</td>
<td>obtuse</td>
<td>straight</td>
<td>red-purple</td>
<td>21.75</td>
</tr>
<tr>
<td>Khunwar themwe</td>
<td>AAA</td>
<td>pointed</td>
<td>slightly</td>
<td>straight</td>
<td>yellow</td>
<td>20.50</td>
</tr>
<tr>
<td>Giant Cavendish</td>
<td>AAA</td>
<td>slightly</td>
<td>pointed</td>
<td>straight</td>
<td>green</td>
<td>20.50</td>
</tr>
<tr>
<td>Dwarf Cavendish (Themwe)</td>
<td>AAA</td>
<td>pointed</td>
<td>slightly</td>
<td>straight</td>
<td>yellow</td>
<td>22.08</td>
</tr>
<tr>
<td>Bluggae</td>
<td>ABB</td>
<td>blunt</td>
<td>obtuse</td>
<td>straight</td>
<td>yellow rusty</td>
<td>16.22</td>
</tr>
<tr>
<td>Mysore (Rakhine)</td>
<td>ABB</td>
<td>ovoid</td>
<td>intermediate</td>
<td>straight</td>
<td>yellow</td>
<td>14.30</td>
</tr>
<tr>
<td>Butter(silk) (Htawbut)</td>
<td>AAB</td>
<td>blunt</td>
<td>obtuse</td>
<td>straight</td>
<td>rusty brown</td>
<td>20.00</td>
</tr>
<tr>
<td>Pya Ye Sam</td>
<td>AAB</td>
<td>ovoid</td>
<td>obtuse</td>
<td>straight</td>
<td>yellow rusty</td>
<td>21.90</td>
</tr>
<tr>
<td>Ngel-Phyar</td>
<td>ABB</td>
<td>blunt</td>
<td>pointed</td>
<td>straight</td>
<td>rusty brown</td>
<td>16.00</td>
</tr>
<tr>
<td>Sar Galay</td>
<td>AA</td>
<td>ovoid</td>
<td>-</td>
<td>curve in distal</td>
<td>yellow</td>
<td>14.50</td>
</tr>
<tr>
<td>Sin Ann</td>
<td>ABB</td>
<td>blunt</td>
<td>obtuse</td>
<td>-</td>
<td>-</td>
<td>16.50</td>
</tr>
<tr>
<td>Thanda Ni</td>
<td>AAA</td>
<td>ovoid</td>
<td>obtuse</td>
<td>straight</td>
<td>green</td>
<td>24.50</td>
</tr>
<tr>
<td>Thanda Ni</td>
<td>AAA</td>
<td>ovoid</td>
<td>obtuse</td>
<td>straight</td>
<td>reddish brown</td>
<td>24.50</td>
</tr>
<tr>
<td>Green Red</td>
<td>AAB</td>
<td>ovoid</td>
<td>obtuse</td>
<td>curved in distal</td>
<td>green</td>
<td>19.50</td>
</tr>
<tr>
<td>Nan Thar Pu</td>
<td>AAA</td>
<td>ovoid</td>
<td>obtuse</td>
<td>-</td>
<td>-</td>
<td>21.00</td>
</tr>
</tbody>
</table>

Table 2. Exotic cultivars, genotype and characteristics (Sein Hla Bo).

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Source</th>
<th>Genome group</th>
<th>Flower bud shape</th>
<th>Leaf Tip</th>
<th>Fruit shape</th>
<th>Fruit peel color</th>
<th>TSS (Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavendish (Williams)</td>
<td>Israel</td>
<td>AAA</td>
<td>pointed</td>
<td>straight</td>
<td>yellow (green)</td>
<td>pinkish yellow</td>
<td>21.40</td>
</tr>
<tr>
<td>Barangan (LKB-1)</td>
<td>LKB.Bio</td>
<td>AAB</td>
<td>blunt</td>
<td>straight</td>
<td>pinkish yellow</td>
<td>yellow</td>
<td>20.00</td>
</tr>
<tr>
<td>Giant Cavendish (Singapore)</td>
<td>Singapore</td>
<td>AAA</td>
<td>pointed</td>
<td>slightly</td>
<td>pointed</td>
<td>yellow</td>
<td>19.50</td>
</tr>
<tr>
<td>Dwarf Cavendish (Green)</td>
<td>Singapore</td>
<td>AAA</td>
<td>pointed</td>
<td>slightly</td>
<td>pointed</td>
<td>yellow</td>
<td>24.00</td>
</tr>
<tr>
<td>Dwarf Cavendish (Green)</td>
<td>India</td>
<td>AAA</td>
<td>pointed</td>
<td>slightly</td>
<td>pointed</td>
<td>green</td>
<td>21.5</td>
</tr>
</tbody>
</table>

resistance to pests and diseases. For the exotic cultivars, the adaptability tests were conducted in lowland Myanmar, including their performance and quality. Based on the local demand and customer preference, the variety selections were observed for yield, fruit quality and shelf-life through multi-location tests.

**Cultural practices**

For the crop improvement strategy, different planting systems, cultural practices, fertilizer application rate and water management play key
roles for yield and quality of banana. Standard planting density is 5 m x 5 m. For the trials, 2.55 m x 2.55 m planting density is used due to the adaptation of growers in major banana production areas that lead to nearly four times increment of plant population. However, further research activities should be implemented. Also, appropriate dosage of fertilizer application is required for preventing the lodging of banana, especially for giant cultivars. For this purpose, future research activities will be extended in the area of nutrient requirement, timing and amount of application, irrigation scheduling and crop water requirement in different locations.

**Multiplication methods**

The popular cultivars were selected to help meet the increasing demand for planting materials. The two multiplication methods were propagation by suckers and division of eye-buds. Results showed that one sucker can produce at least (4-8) eye buds in Dwarf Cavendish that can grow well into new plants like suckers.

**Tissue culture**

The micro-propagation technique in banana was successfully operated at the VFRDC tissue-culture laboratory under Myanma Agriculture Service since 1987. This activity enhances the rapid multiplication of
good-quality banana varieties. Likewise, the conservation of germplasm was done by this technique. At present, 15 banana varieties were produced and distributed to the growers. VFRDC plans to produce 300,000 plantlets from 2004 to 2005 by tissue culture. Through this rapid method, the increasing demand of the growers will be met.

**Postharvest handling**

Postharvest losses of banana range from 20-80% in Myanmar were caused by problems in transportation, packing and marketing systems. These losses may be attributed to physiological and mechanical damage, and pests and diseases. Due to the soft texture and high moisture content, banana is more susceptible to mechanical injury. Thus, growers and distributors need to do careful handling for packing, transportation and storage. On the other hand, the technology for post-harvest handling, temperature control, control atmosphere storage and control of shelf-life is needed. Thus, research activities were conducted in VFRDC.

The effect of KCl on fruit quality of Cavendish banana was tested and shown in Table 4.

**Table 4. Effect of KCl on fruit quality of Cavendish banana (VFRDC, Yangon 1998).**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stem height (cm)</th>
<th>Fruit weight (m)</th>
<th>Hand weight (kg)</th>
<th>TSS (Brix)</th>
<th>Resistance to lodging</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCl (450 gm/plt)</td>
<td>171-220</td>
<td>169.30</td>
<td>2.50</td>
<td>21.50</td>
<td>1.30</td>
<td>VFRDC(D4)</td>
</tr>
<tr>
<td>KCl (900 gm/plt)</td>
<td>171-235</td>
<td>190.00</td>
<td>2.70</td>
<td>21.70</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>KCl (1200gm/plt)</td>
<td>171-260</td>
<td>193.10</td>
<td>2.95</td>
<td>22.50</td>
<td>0.50</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>171-230</td>
<td>170.40</td>
<td>2.73</td>
<td>20.00</td>
<td>2.10</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>-</td>
<td>17.52</td>
<td>0.53</td>
<td>0.98</td>
<td>14.87</td>
<td></td>
</tr>
<tr>
<td>LSD (5%)</td>
<td>-</td>
<td>13.41</td>
<td>2.49</td>
<td>2.24</td>
<td>0.74</td>
<td></td>
</tr>
</tbody>
</table>

As mentioned earlier, the growers are less aware of pest and disease problems. Major pest and disease problems are on stem borer infestation and anthracnose disease in some area. In VFRDC, IPM implemented on preharvest field conditions influenced the postharvest quality of banana. Results showed that Anthracnose incidence is reduced and increased yield and leaf numbers are observed.

Likewise, chemical treatment, packaging material, controlled atmosphere and other necessary research depend on development of banana production.
Constraints in banana R&D

- Lack of extension staff for horticulture crops
- Limited budget for extensive demonstration plots
- Limited research funding
- Continuous technology transfer to farmers
- Capacity building of staff.

Conclusion

Myanmar endeavours to improve banana R&D through more research activities. Likewise, Myanmar aims to collect banana germplasm and to have technical collaboration with other governments, different organizations and agencies. Knowledge gained from this meeting will be applied to help improve the banana R&D in the country.
Highlights of banana R&D in Papua New Guinea

Rosa N. Kambuou

Banana production in Papua New Guinea is still at the subsistence level. Over 85% of the rural farmers throughout the country are growing some varieties of bananas for their own household consumption and the surplus is sold cheaply in the local fresh food markets. Only a few farmers had taken interest in venturing into banana production on monoculture set-ups in small commercial scale. A large quantity of banana produced in the country is mostly consumed on farm while selected cultivars are taken to urban markets for sale.

Emphasis on banana research has been minimal at this stage. The current research activities on banana focus on conservation and maintenance of banana genetic diversity in field genebanks, preliminary selection of promising cultivars for dry conditions and multiplication of planting materials of selected superior cultivars for farmers. This report will discuss the highlights of the banana research and development activities undertaken in PNG for the last two years.

Significance of banana R&D in PNG

The PNG National Agricultural Research Institute (NARI) is the main research organization on food crops including bananas. The PNG Cocoa Coconut Research Institute (CCI) and the Coffee Research Institute (CRI) are doing some work on bananas, but in intercropping studies with coffee, coconut or cocoa.

Few individuals or institutions in the country are growing bananas as mono-crop on small commercial scale. Emphasis is placed on dessert bananas for the urban markets in Port Moresby and Lae.

The bulk production of bananas comes from the informal sector that makes up of over 85% of the people living in rural areas of the country. Production from the informal sector focuses mostly on cooking bananas rather than dessert bananas.

Research activities

The current research focus on banana is in the following areas:

- germplasm conservation, management and use

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Advancing banana and plantain R&D in Asia and the Pacific - Vol 13

- plant protection studies, looking at fruit fly and banana scab damage
- evaluation of the sigatoka-resistant IMTP materials and hybrids
- bulking up of the sigatoka-resistant materials for G x E studies next year
- multiplication of planting materials of drought-tolerant varieties for on-farm studies
- multiplication and distribution of planting materials of varieties tolerant to drought conditions

National Banana Germplasm Collection (Field genebank)

The National Germplasm Collection has 235 accessions held in the field genebank by NARI at Laloki. Most of these accessions are cooking types from the diploid and triploid genomes. There are few tetraploids in the collection. The wild species were collected in the past, but failed to establish in ex situ field collections. The whole national collection has been morphologically characterized. Information on preliminary evaluation of bunch yields are incomplete due to fruit loss through stealing of banana bunches. Information and data collected were entered into MGIS database. The preliminary evaluation information enabled the national curator to do the initial selection of three banana varieties that are tolerant to dry conditions. The varieties ‘Dwarf Kalapua,’ ‘Small Kalapua’ and ‘Tall Kalapua’ are from the ABB genome. The other varieties selected by the farmers that survived the El Nino drought were ‘Dwarf Cavendish’ and ‘Yawa.’

Planting materials of the selected drought-tolerant varieties are multiplied and distributed to farmers throughout the dry-lowland areas. Research proposals are developed for testing these selected varieties at different dry land locations in the country.

Sigatoka-resistant banana varieties/hybrids from IMTP

PNG received a total of 14 sigatoka-resistant banana varieties and hybrids from the Department of Primary Industries (DPI), Queensland and the second batch of 16 materials from the INIBAP International Transit Centre (ITC). The materials from the first batch were tested under the irrigated condition at NARI Laloki where interesting results were obtained. All the FHIA hybrids showed high resistance to sigatoka disease and produced very heavy bunches. FHIA-25 produced the highest bunch weight of 38 kg while FHIA-17 and SH-3436 produced 20 and 21 kg, respectively. The most favoured variety in terms of taste was ‘Pisang Ceylan’ with 17 kg per bunch (refer to ‘Banana hybrids/
varieties tested for sigatoka disease resistance under irrigated conditions of Laloki Papua New Guinea’).

Investigations were carried out on consumer’s preference of these varieties as dessert bananas. The results showed that most consumers preferred variety ‘Pisang Ceylan,’ and hybrids FHIA-02, FHIA-17, FHIA-23 and SH-3436 (refer to ‘Banana hybrids/varieties tested for Sigatoka disease resistance under irrigated conditions of Laloki Papua New Guinea’). Based on the results of this study, NARI took the opportunity during the official opening of its Headquarters last year to officially release these five varieties to the farmers for on-farm testing.

The second batch of sigatoka-resistant materials that came from ITC is being multiplied at NARI Keravat for multi-location studies in 2005.

**Banana fruit fly and scab studies**

NARI entomologists based at Keravat are currently carrying out studies on banana fruit flies and scab. Their work has showed that fruit flies and scab are serious pests of bananas and can cause economic yield reduction under large mono-cropping situations if control measures are not taken. At the moment the damage by these pests is not so significant because the production is still at the subsistence level.

**Banana intercrop with cash crops**

The commodity research institutes carry out research on PNG’s revenue earning crops like cocoa, coconut and coffee. CCI is undertaking studies on cocoa and coconut intercropping with bananas and other food crops. Their whole purpose is to find out which food crop species would be suitable for growing with the tree cash crops. The banana intercropping with coconut and cocoa is currently carried out at Stewart Research Institute in Madang. While the banana intercropping with coffee is conducted by CRI at Aiyura, results from these studies were not available at the time of writing this report.

**Development and production activities**

Banana development and production will be discussed under the formal and the informal sector production. The formal sector production refers to the commercial production of bananas in the country and the informal sector production includes the subsistence-level production.

**Formal or semi-commercial sector**

There are four semi-commercial farmers who are growing dessert
bananas such as Cavendish, Williams and Gros Michel for the urban markets of Lae and Port Moresby. The Pacific Adventist University (PAU) farm just outside Port Moresby is producing around 30 t/ha of banana for the urban fresh fruit markets.

The other three semi-commercial producers are based outside the city of Lae. The farms owned by Messrs Samana, Philemon and Jacobson are all-producing bananas on semi-commercial scale for the supermarkets in Lae. They grow both the dessert and the cooking varieties. Cavendish is the main variety grown by these farmers with a number of popular local diploids for cooking. There may be other semi-commercial banana growers in PNG that the author may not be aware of. The author believes that commercial production of banana in PNG is insignificant thus calls for the government support to develop the formal sector banana production.

**Informal/subsistence sector**

It is not clear how many tonnes of banana- subsistent farmers in the country produce. Banana is usually intercropped with other food crops in a mixed cropping manner making it very difficult to estimate production. Informal sector production is based mostly on cooking varieties. Farmers from different areas prefer their own indigenous varieties. The triploid ABB varieties are grown mostly in the drier parts of the country while the diploids are commonly grown in the wet lowland and island areas. The triploid AAB varieties are commonly cultivated in the highland areas of the country.

**Development and use of banana through downstream processing**

In PNG, banana is consumed as fresh fruits or as staple food crop cooked in coconut cream, baked or steamed with hot stones in earth oven. The processed banana products sold and eaten in PNG are imported from other countries. There are interested groups making their own banana chips for own consumption, but the production is minimal at this stage. There is a need in the country to go into downstream processing of banana to produce products that have high value and long shelf-life. Capacity building in the area of downstream processing is required.

**Capacity-building activities**

Capacity building has mostly been in the area of technical skills training in the production of bananas. NARI Laloki has been responsive to
training requests from farmers and service providers. Hands-on training and farm demonstrations on ‘banana bit’ technique as a means of rapidly multiplying planting materials has been offered to farmers and service providers for a number of times. Many farmers and backyard gardeners in Central Province are successfully using this technique for producing planting materials. This instigated NARI to officially release the ‘banana bit’ technique to farmers during its Dry-lowlands Programme Open Day this year.

PNG did not participate in the Musa Documentation Training and the Workshop held in Malaysia in December 2003 due to ticketing problem. It would be beneficial for PNG to participate in future training and workshops on documentation or other aspects of banana research and development.

**Status of National Repository Project**

The IMTP varieties received from QDPI that were tested in the study conducted at Laloki are now being maintained alongside the National Banana Germplasm Collection located at Laloki. Of the total of 14 varieties, five were released to the farmers based on their high bunch yields, resistance to sigatoka and good eating quality as fresh fruits. Planting materials of varieties FHIA-02, FHIA-17, FHIA-23, SH-3436 and Pisang Ceylan are currently being multiplied for distribution to farmers. The results from the study conducted under the irrigated condition of Laloki are presented in another paper (refer to ‘Banana hybrids/varieties tested for sigatoka-disease resistance under irrigated conditions of Laloki Papua New Guinea’).

Few planting materials of the five sigatoka resistant varieties were given to selected subsistence-level farmers and three semi-commercial farms for on-farm testing. Once sufficient planting materials are multiplied, more farmers will be selected for collaboration in on-farm testing of these varieties.

The other 16 IMTP materials from the ITC are held under tissue culture condition at NARI Keravat. These materials are currently being multiplied for G x E studies at multi-location sites next year. There are plans to test these materials against the common local varieties at four different agro-ecological zones in 2005.

**Publications on bananas**

Since last year, NARI published a number of books and articles on banana research activities. The ‘banana bit’ technique was written up
as a NARI Toktok, a publication for the farmers and service providers. Two released documents were written on the ‘banana bit’ technique and the five sigatoka-resistant varieties. These released documents were given with the ‘banana bit’ planting materials to farmers and representatives of the service providers.

The general information on PNG’s rich genetic diversity of bananas was published in two national newspapers, the Post Courier and the National.

**Government policy and support**

Banana is one of the main staple food crops of PNG. There is a national interest in developing the crop. However, inadequate technical and scientific capacity has hindered progress in research and development of banana. NARI has been supportive on banana research by including banana activity in its research programme. There is no government policy on banana development in the country. PNG was importing all its dessert bananas from Australia in the last 10 years. Since 2000, the Government has introduced a policy on importation of certain fresh food items including dessert bananas that encouraged the small farmers and semi-commercial farmers to go into dessert banana production. However, no assistance was given by the government in terms of establishment of market infrastructure to encourage farmers to produce bananas for the domestic market. That is the main hindrance to farmers’ lack of interest in producing the crop on large scale. There is also a need for a national policy and government support in developing the domestic banana industry in PNG.

**Areas of collaboration**

The possible areas of collaboration include the following:

- **Research**
  - Collaboration in studies on major and important pests and diseases of bananas
  - Research on postharvest and downstream processing of bananas
  - Capacity building in DNA finger printing of the banana germplasm collection to assist in the selection of the ‘core collection’ from the current national germplasm collection for conservation purposes

- **Development**
  - Capacity building in techniques and skills of downstream processing of banana through cottage industries
Banana is one of the major income-generating commodities in the country. It is an important source of income for small farmers who constitute almost 75% of the banana growers. It is grown throughout the country either as a component of existing farming systems or as the main crop in large commercial plantations.

The country is blessed with favourable climate for growing quality bananas such that multinational investors established large commercial plantations in Mindanao, the southern part of the Philippines. For several decades, the Philippine ‘Cavendish’ banana, produced from these plantations, was popular in the world market. However, the area for commercial plantations (10%) is very negligible compared with the total area of smallholder subsistence farms. Moreover, the production systems being practised are entirely different in these two farms; hence, a big gap exists between these farms in terms of the productivity per unit area. In this regard, the government is putting much effort to improve the productivity of the smallholder farms, where most of the important local cultivars such as ‘Saba’, ‘Lakatan’, and ‘Latundan’ are being grown.

The Strategic Action Plan for Banana, drafted by the Department of Agriculture (DA) through the National Agriculture and Fishery Council (NAFC) and Philippine Genetics, Inc. in 2002, covers the plan for ‘Lakatan’, ‘Latundan’, and ‘Saba’/’Cardaba’ grown by majority of small- and medium-scale growers in order to enhance the productivity and further develop the industry as a whole. This is in congruence with the Medium-term Development Plan of the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) that considers the Banana R&D Program for the particular benefit of smallholder farmers.

Moreover, in the crafting of the Industry Strategic Plan for Banana this year, as initiated by the National Academy of Science and Technology (NAST) in coordination with PCARRD, the same thrusts and programmes will be adhered to, and the plan will be expanded until 2020. Incidentally, the Banana Asia Pacific Network (BAPNET) also shares similar thrusts of enhancing the productivity of smallholder farmers.

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*Executive Director, PCARRD, Los Baños, Laguna, Philippines.
banana growers in the region through information sharing among member-countries.

**Banana R&D status**

**R&D Investments**

From 1991 to 2004, the total investments for banana R&D in the country amounted to ₱76.23 million (US$1.386 million), coming from both local and foreign funding agencies (Table 1). These investments primarily aimed to develop technologies for the production of disease-free planting materials, screen different cultivars against major pests and diseases, improve the management systems for major cultivars, develop/improve the products both for local and export markets, maintain germplasm in the field and in vitro, develop diagnostic kits for viral diseases, improve postproduction techniques, and develop action programmes for the rehabilitation of diseased farms.

<table>
<thead>
<tr>
<th>Status of Project</th>
<th>Source of Funds ($)</th>
<th>DOST</th>
<th>PCARRD</th>
<th>DA-BAR</th>
<th>Agency-funded</th>
<th>INIBAP*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>480 676</td>
<td>216 768</td>
<td>568 414</td>
<td>85 212</td>
<td>35 206</td>
<td></td>
</tr>
</tbody>
</table>

**Current banana R&D thrusts and priorities**

The various stakeholders of the banana industry gave priority to enhancing the production and quality of the major local cultivars ‘Saba,’ ‘Lakatan,’ and ‘Latundan’ that are being grown by the subsistence or smallholder farmers. In line with this, the current R&D priority for banana is focused on enhancing the competitiveness of the Philippine banana sub-industry (fresh and processed) for the domestic and export markets by improving the productivity of the smallholder farmers under a community-based farming operation.

The banana sub-industry includes: a) the quality production of ‘Saba’ and other improved cultivars for chips and other new products for the export market; and b) the improved production of ‘Lakatan,’ ‘Latundan,’ and other improved cultivars for the fresh local market. In addition, the postproduction, processing, and packaging for processed products will be given attention to provide added value to banana. Alongside these efforts will be the continuing activity of concerned agencies on maintaining germplasm and improving the cultivars.
**Current banana R&D highlights**

**Introduction, evaluation and adoption of improved landraces of banana for food and income alleviation**

Ms Lorna Herradura, Bureau of Plant Industry-Davao National Crop Research and Development Center (BPI-DNCRDC) and Dr Felipe dela Cruz, Institute of Plant Breeding at the University of the Philippines Los Baños (IPB-UPLB) head this project which is being funded by the International Network for the Improvement of Banana and Plantain (INIBAP) and the DA-Bureau of Agricultural Research (BAR). Below are the objectives and summary of accomplishments of the project:

1. **Germplasm maintenance, multiplication, and distribution of improved and superior banana varieties at BPI-DNCRDC and IPB-UPLB**

   The BPI-DNCRDC and IPB-UPLB are maintaining local and introduced *Musa* varieties as foundation stocks (Table 2). These accessions are intended for multiplication/evaluation in selected areas and distribution to interested farmers. The newly introduced varieties will be registered jointly by BPI-DNCRDC and IPB-UPLB at the Philippine Plant Variety Protection Office.

   The materials at IPB-UPLB are being maintained *in vitro* in rooting and multiplication media and regularly subcultured in fresh medium every 2 months. All varieties maintained in the rooting medium are planted in pots inside the screenhouse. These materials serve as foundation stocks and are indexed regularly.

   IPB-UPLB is also maintaining a field demonstration plot of the introduced and local varieties. This serves as a showcase of the different banana cultivars and is visited by farmers, researchers and students.

   The materials in the screenhouse at BPI-DNCRDC are in clay pots. The recommended management practices (fertilization, pesticide spraying, sanitation like deleafing or leaf pruning, weeding and watering) for these improved varieties are regularly done. Leaf samples were already analyzed for virus indexing and were all found to be negative for bract mosaic virus.

2. **Farmer participatory characterization, evaluation and selection of improved and superior banana varieties at BPI-DNCRDC**

   At BPI-DNCRDC, field planting was conducted within the experiment station for monitoring and collecting data for agronomic characteristics. Promising varieties were selected and subjected to further evaluation in a farmer’s field. Four banana and plantain
Table 2. List of accessions maintained at IPB-UPLB and BPI-DNCRDC, as of September 2004.

<table>
<thead>
<tr>
<th>ITC Code</th>
<th>Accession Name</th>
<th>IPB-UPLB</th>
<th>BPI-DNCRDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITC. 0312</td>
<td>‘Pisang Jari Buaya’</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 0504</td>
<td>FHIA-01</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 0505</td>
<td>FHIA-02</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 0506</td>
<td>FHIA-03</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 0570</td>
<td>‘Williams’ (Bell, SJ)</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 0643</td>
<td>‘Cachaco’</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 0712</td>
<td>‘AAcv Rose’</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1122</td>
<td>‘Gros Michel’</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1123</td>
<td>‘Yangambi km 5’</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1264</td>
<td>FHIA-17</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1265</td>
<td>FHIA-23</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1282</td>
<td>GCTCV-119</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1283</td>
<td>SH 3436-9</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1296</td>
<td>TMB x 1378</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1297</td>
<td>TMB x 5295-1</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1307</td>
<td>SH 3640</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1319</td>
<td>FHIA-18</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1332</td>
<td>FHIA-21 (#68)</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1344</td>
<td>CRBP 39</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1417</td>
<td>TMB x 15108-6</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1418</td>
<td>FHIA-25</td>
<td>in vitro</td>
<td>in vitro</td>
</tr>
<tr>
<td>ITC. 1441</td>
<td>‘Pisang Ceylan’</td>
<td>in vitro</td>
<td>screenhouse</td>
</tr>
<tr>
<td>ITC. 1442</td>
<td>GCTCV-106</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td>ITC. 1443</td>
<td>GCTCV-247</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Cavendish’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Cardaba’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Bungulan’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Lakatan Davao’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Lakatan Cavite’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Lakatan Mindoro’</td>
<td>in vitro</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Quarenta Dias’</td>
<td>in vitro</td>
<td></td>
</tr>
</tbody>
</table>

hybrids (FHIA-03, FHIA-18, FHIA-21, and FHIA-23) and two local check cultivars (‘Cardaba’ and ‘Lakatan’) were planted for the farmer’s field trial.

Banana bunchy top virus (BBTV) was prevalent in the area near the experimental site. Although the farmer cautiously checked the spread of the disease by regularly removing infected plants, a few test plants exhibited clear symptoms of BBTV. In April 2004, 27 plants were eradicated because of BBTV and fusarium wilt. To replace the eradicated plants, data will be collected from extra test plants.

FHIA-18 was the earliest to flower, followed by FHIA-03 and then ‘Lakatan.’ FHIA-03 had the highest average number of functional leaves at shooting, followed by FHIA-18, FHIA-21 and FHIA-23. It was observed that the hybrids generated shoots earlier than the local cultivars and had a higher number of functional leaves at shooting.
From the harvest data, FHIA-03 was the earliest to mature, followed by FHIA-18 and ‘Lakatan.’ The number of functional leaves at harvest was very high in FHIA-03 (10 leaves) compared with that of ‘Lakatan’ (1 leaf). As of April 2004, yield data on ‘Cardaba’ has not been gathered owing to the fruits’ late maturity. It could be observed that the hybrids were far more superior to the local cultivars in terms of yield characteristics (bunch weight, finger weight, number of hands and number of fingers).

Acceptability of the fruits harvested was evaluated in terms of their general appearance, firmness, peduncle strength, postharvest characteristics, resistance to pests and diseases, yield, taste and uses. It was found that FHIA-03, FHIA-21, and FHIA-23 showed good results in terms of yield and taste. It was also observed that FHIA-23 had a long shelf life and an excellent processing quality. However, it was noted that the harvested fruits from banana and plantain hybrids were used as animal feed because of their unfamiliar taste and appearance.

In the future, sensory evaluation will be conducted to assess the acceptability of the produce, agroclimatic data will be gathered, and a second test site will be established.

3. In-depth evaluation against sigatoka and fusarium wilt at BPI-DNCRDC

**Sigatoka**

A total of 16 introduced cultivars, using tissue-cultured plantlets, were used as test plants for evaluation. Disease rating was done following the INIBAP Technical Guidelines. Agronomic and disease ratings were taken from planting to harvest.

Disease and agronomic data showed that the introduced hybrids performed better than the control. Highest youngest leaf spotted (YLS) was observed with FHIA-18. All FHIA’s had a higher YLS than the resistant check, ‘Cardaba.’ Disease development time record showed that the necrotic lesions developed longer in FHIA-01, among all the FHIA’s. Lowest disease severity index at 6 months was obtained from FHIA-01, followed by FHIA-18.

**Fusarium wilt**

A total of 22 introduced cultivars, using tissue-cultured plantlets, were used as test plants for evaluation. Disease and agronomic data collection were collected based on protocols from IMTP Phase II guidelines. Disease monitoring was done weekly.
Nine plants of the local cultivar ‘Latundan’ were infected with fusarium wilt disease. Fourteen months after planting, one plant of FHIA-17, FHIA-23, FHIA-18 and SH 3436-9 was also infected. Pseudostem discoloration was observed to have extended up to the petiole of the plants.

The only hybrids that were able to reach fruit maturity were TMB x 1378, TMB x 1510-6 and SH-3540. Bunch weight obtained from the hybrids ranged from 7.7 to 7.9 kg. Only accession Yangambi km 5 did not reach the shooting stage.

4. Morphological characterization and yield performance at IPB-UPLB

Nineteen introduced varieties, together with seven local varieties to serve as check, were established at the demonstration plot. Morphological characterization was conducted following the Banana Descriptors. Yield evaluation was measured in terms of bunch, hand and finger yield. Characterization and yield evaluation are still ongoing for some of the varieties. Table 3 shows the initial results of the morphological characterization of the introduced accessions.

Table 3. Fruiting characteristics of introduced and local banana cultivars grown at the IPB-UPLB Demo Plot, April 2004.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Bunch weight (kg)</th>
<th>Number of hands</th>
<th>Number of fingers</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Cachaco’</td>
<td>8.6</td>
<td>5</td>
<td>47</td>
</tr>
<tr>
<td>‘cv Rose’</td>
<td>2.1</td>
<td>7</td>
<td>79</td>
</tr>
<tr>
<td>FHIA-01</td>
<td>7.5</td>
<td>7</td>
<td>97</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>6.5</td>
<td>7</td>
<td>102</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>12.9</td>
<td>8</td>
<td>99</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>9.6</td>
<td>7</td>
<td>91</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>11.8</td>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>7.5</td>
<td>4</td>
<td>59</td>
</tr>
<tr>
<td>‘Pisang Ceylan’</td>
<td>10.2</td>
<td>10</td>
<td>144</td>
</tr>
<tr>
<td>‘Pisang Jari Buaya’</td>
<td>8.8</td>
<td>7</td>
<td>102</td>
</tr>
<tr>
<td>SH 3640</td>
<td>11.2</td>
<td>6</td>
<td>76</td>
</tr>
<tr>
<td>TMB X 5295-1</td>
<td>6.6</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>8.8</td>
<td>7</td>
<td>94</td>
</tr>
<tr>
<td>‘Lakatan Cavite’</td>
<td>10.6</td>
<td>6</td>
<td>97</td>
</tr>
<tr>
<td>‘Lakatan Mindoro’</td>
<td>11.3</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>‘Quarenta Dias’</td>
<td>7.4</td>
<td>7</td>
<td>107</td>
</tr>
</tbody>
</table>
5. Sensory and product evaluation at IPB-UPLB

Sensory evaluation of improved and introduced landraces of banana was conducted in three barangays in Los Baños, Calamba City and Bay in the province of Laguna. A total of 131 untrained panelists participated in the sensory evaluation trial. Twenty-four bananas were used in the evaluation. Separate evaluations were done for ripe/uncooked bananas and plantains and for cooked plantains.

Ten characters—finger shape, peel color, hand and finger size, pulp color, pulp size, pulp texture, taste, flavor, sweetness and overall acceptability—were used in evaluating ripe/uncooked bananas and plantains. Cooked plantain was evaluated using the peel color, pulp color, texture, taste, flavor, sweetness and overall acceptability.

The different varieties were ranked for every location, which can be used as the basis for determining the varieties for distribution. The results showed that respondents from different locations had varied preferences which necessitated the multiplication of different sets for various sites. In general, the results revealed that ‘Lakatan’ was more preferred than other ripe/uncooked banana and plantain varieties across locations, while ‘Saba’ topped the other plantains when cooked.

Three introduced cultivars (FHIA-21, TMB x 5295-1 and CRBP 39) were evaluated for their potential for processing as banana chips, powder and catsup. While variations in color of chips and powder were observed, all three varieties were rated acceptable for processing.

Banana collaborative RDE project in Luzon areas

Cavite State University (CvSU), Don Mariano Marcos Memorial State University (DMMMSU), Quirino State University (QSC), Southern Luzon Polytechnic College (SLPC), Pampanga Agricultural College (PAC), Mindoro State College of Agriculture and Trade (MinSCAT), Ilocos Sur Polytechnic State College (ISPSC), Virlanie Foundation Inc are the collaborators of this INIBAP-PCARRD-funded project.

The project evaluated four improved banana cultivars (FHIA-01, FHIA-03, FHIA-18, FHIA-23) introduced by INIBAP, along with two local cultivars (‘Bungulan’ and ‘Lakatan’), under farmers’ fields. The project started in 2002 with only three SCUs, and was later expanded. The project aims to evaluate the introduced disease-resistant varieties as alternative or complimentary cultivars with the local cultivars. Also, the adoption of appropriate production systems for optimum yield and maximum fruit quality is being introduced to the cooperators. To
date, 77,500 tissue-cultured planting materials of the different introduced and local cultivars have been distributed to farmer cooperators in the test locations.

About seven training programmes were conducted, benefiting 87 project staff, farmer cooperators and municipal agricultural officers in the various project sites. The training programmes included nursery and field management, diseases and pest management and production systems of tissue-cultured bananas that were already at their fruiting stage. Most of the cooperators grew the tissue-cultured bananas. In general, the cooperators were satisfied with the performance of their plants, which they usually compared with their previous plants grown from suckers. Very minimal incidence of BBTV was observed in the test locations. However, the grower acceptability of the produce, especially of the introduced varieties, will still be determined.

The following are the highlights of accomplishment of the different project sites as of September 2004:

**LOA 2002/21 DMMMSU, Bacnotan, La Union/ Dr Felino Neri**

- This location was the first to conduct the field evaluation trials. The trials were done in three different agro-ecological conditions: lowland upland, semi-upland rainfed and coastal zones.

- Based on the agronomic characteristics of the promising banana cultivars evaluated in the different locations in La Union, the earliest variety to shoot was FHIA-23 while the latest was ‘Bungulan’ (Table 4). It follows that ‘Bungulan’ matured the earliest, while FHIA-23 was the latest. FHIA-23 had the largest pseudostem girth while ‘Bungulan’ had the smallest. However, ‘Bungulan’ produced the highest number of suckers, while FHIA-03 had the least. The maturation period of the different cultivars was greatly affected by the varying agro-ecological zones. Most varieties matured late under a coastal/rainfed condition.

- Table 5 shows the initial data on the yield and yield components of promising banana cultivars in different locations in La Union. The results revealed that FHIA varieties gave higher yield in Sudipen, La Union. FHIA-03 had the highest yield, followed by FHIA-21 and FHIA-23. Under coastal and upland conditions, FHIA-03 also produced the highest yield. The initial results showed that FHIA-03 gave the highest yield under favourable and unfavourable conditions. However, FHIA-21 and FHIA-23 seemed to have been affected by drought conditions. The number of days to shooting seemed to be longer in areas with sandy soil and drought conditions.
Table 4. Agronomic characteristics of promising banana cultivars measured at harvest in La Union, 2004.

<table>
<thead>
<tr>
<th>Ecological zone/Soil type</th>
<th>Location/variety</th>
<th>Date planted</th>
<th>Planting to shooting (days)</th>
<th>Height of sucker (cm)</th>
<th>Height of pseudo-stem (cm)</th>
<th>Girth of pseudo-stem (cm)</th>
<th>No. of suckers</th>
<th>No. of functional leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowland rainfed/clay loam</td>
<td>Sudipen A</td>
<td>14 Dec. 2002</td>
<td>14 Dec. 2002</td>
<td>164.00</td>
<td>312.00</td>
<td>60.00</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>‘Lakatan’</td>
<td>350</td>
<td>164.00</td>
<td>312.00</td>
<td>60.00</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Bungulan’</td>
<td>287</td>
<td>184.00</td>
<td>290.00</td>
<td>42.00</td>
<td>7</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-03</td>
<td>308</td>
<td>177.80</td>
<td>284.00</td>
<td>61.00</td>
<td>2</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-21</td>
<td>354</td>
<td>105.00</td>
<td>203.00</td>
<td>56.00</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-23</td>
<td>480</td>
<td>182.40</td>
<td>285.20</td>
<td>76.00</td>
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<td>8</td>
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</tr>
<tr>
<td>Lowland rainfed/clay loam</td>
<td>Sudipen B</td>
<td>14 Dec. 2002</td>
<td>14 Dec. 2002</td>
<td>85.50</td>
<td>339.5</td>
<td>56.50</td>
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<td>339.5</td>
<td>56.50</td>
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<td>4.5</td>
<td></td>
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<tr>
<td>‘Bungulan’</td>
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<tr>
<td>FHIA-03</td>
<td>347</td>
<td>199.88</td>
<td>265.82</td>
<td>62.12</td>
<td>2</td>
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<tr>
<td>FHIA-21</td>
<td>345</td>
<td>169.24</td>
<td>321.50</td>
<td>62.89</td>
<td>6</td>
<td>5</td>
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<tr>
<td>FHIA-23</td>
<td>413</td>
<td>172.00</td>
<td>313.10</td>
<td>80.0</td>
<td>4</td>
<td>8</td>
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<tr>
<td>Semi upland rainfed/silty loam</td>
<td>DMMSU</td>
<td>5 Dec 2002</td>
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<tr>
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<td>72.88</td>
<td>167.88</td>
<td>32.00</td>
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<tr>
<td>‘Bungulan’</td>
<td>286</td>
<td>125.67</td>
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<td>36.00</td>
<td>6</td>
<td>5</td>
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<tr>
<td>FHIA-03</td>
<td>268</td>
<td>99.33</td>
<td>187.00</td>
<td>42.11</td>
<td>3</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-21</td>
<td>435</td>
<td>75.00</td>
<td>172.00</td>
<td>31.50</td>
<td>2</td>
<td>5</td>
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<tr>
<td>FHIA-23</td>
<td>450</td>
<td>82.50</td>
<td>175.00</td>
<td>36.00</td>
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<td></td>
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<tr>
<td>Coastal/sandy loam</td>
<td>Sipulo</td>
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<td></td>
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<tr>
<td>‘Lakatan’</td>
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<td>45.00</td>
<td>330.00</td>
<td>56.00</td>
<td>7</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Bungulan’</td>
<td>500</td>
<td>190.00</td>
<td>230.00</td>
<td>69.50</td>
<td>7</td>
<td>3.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-03</td>
<td>473</td>
<td>210.00</td>
<td>285.00</td>
<td>60.33</td>
<td>3</td>
<td>6</td>
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<td></td>
</tr>
<tr>
<td>FHIA-21</td>
<td>500</td>
<td>231.5</td>
<td>235.00</td>
<td>47.00</td>
<td>4</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-23</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- In terms of pest observations, FHIA varieties showed resistance to sigatoka diseases while the check varieties ‘Lakatan’ and ‘Bungulan’ were susceptible. Bunchy top virus (BTV) disease was minimally observed in the area.
- Table 6 shows the organoleptic characteristics of promising banana cultivars. ‘Lakatan’ still showed the best evaluation. FHIA-03, FHIA-21 and ‘Bungulan’ were very good, while FHIA-23 was good.

**LOA 2003/03 CvSU, Indang, Cavite/Dr Simeon Crucido**

- The first set of planting done in June 2003 using FHIA-03, FHIA-21, FHIA-23, ‘Lakatan,’ and ‘Bungulan’ in four different ecological zones reached maturity stages and had several valuable results (Tables 7 and 8).
- Statistical analysis will still be done to clearly show the differences among cultivars under different growing conditions.
- However, based on the data presented, most cultivars performed well under lowland irrigated, and upland hilly conditions. FHIA-21 seemed to be the best yielder, followed by FHIA-23.
Table 5. Agronomic characteristics of promising banana cultivars at harvest in La Union, 2004.

<table>
<thead>
<tr>
<th>Location/ Variety</th>
<th>Bunch weight (kg)</th>
<th>Mean number of hands/bunch</th>
<th>Mean number of fingers/bunch</th>
<th>Total weight of marketable fruits (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sudipen A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Lakatan’</td>
<td>8.20</td>
<td>8.00</td>
<td>70.00</td>
<td>7.00</td>
</tr>
<tr>
<td>‘Bungulan’</td>
<td>8.36</td>
<td>5.75</td>
<td>69.25</td>
<td>7.68</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>18.68</td>
<td>8.80</td>
<td>119.00</td>
<td>17.43</td>
</tr>
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<td>17.74</td>
<td>7.40</td>
<td>100.80</td>
<td>16.62</td>
</tr>
<tr>
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<td>16.90</td>
<td>9.2</td>
<td>125.14</td>
<td>15.87</td>
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<tr>
<td>‘Lakatan’</td>
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<td>7.45</td>
<td>101.55</td>
<td>13.28</td>
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<tr>
<td>‘Bungulan’</td>
<td>8.50</td>
<td>5.00</td>
<td>68.00</td>
<td>6.50</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>20.88</td>
<td>9.50</td>
<td>13.50</td>
<td>19.12</td>
</tr>
<tr>
<td>FHIA-21</td>
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<td>7.80</td>
<td>106.50</td>
<td>19.18</td>
</tr>
<tr>
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<td>17.72</td>
<td>9.2</td>
<td>127.45</td>
<td>16.70</td>
</tr>
<tr>
<td><strong>DMMMSU</strong></td>
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</tr>
<tr>
<td>‘Lakatan’</td>
<td>2.58</td>
<td>3.86</td>
<td>30.71</td>
<td>2.09</td>
</tr>
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<td>‘Bungulan’</td>
<td>4.02</td>
<td>4.33</td>
<td>35.33</td>
<td>3.33</td>
</tr>
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<td>4.72</td>
<td>5.28</td>
<td>59.57</td>
<td>4.34</td>
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<td>2.0</td>
<td>3.80</td>
<td>35.0</td>
<td>1.80</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>1.97</td>
<td>4.5</td>
<td>40.2</td>
<td>1.77</td>
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<td><strong>Sipulo</strong></td>
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<td>‘Lakatan’</td>
<td>9.20</td>
<td>5.0</td>
<td>77.0</td>
<td>8.2</td>
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<td>‘Bungulan’</td>
<td>8.0</td>
<td>5.0</td>
<td>62.5</td>
<td>7.40</td>
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<tr>
<td>FHIA-03</td>
<td>12.10</td>
<td>7.0</td>
<td>94.00</td>
<td>11.28</td>
</tr>
<tr>
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<td>5.15</td>
<td>5.0</td>
<td>50.20</td>
<td>4.75</td>
</tr>
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<td>FHIA-23</td>
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</tbody>
</table>


<table>
<thead>
<tr>
<th>Variety</th>
<th>Aroma</th>
<th>Texture</th>
<th>Organoleptic characteristics</th>
<th>General evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Lakatan’</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Very sweet</td>
<td>Excellent</td>
</tr>
<tr>
<td>‘Bungulan’</td>
<td>Very good</td>
<td>Very good</td>
<td>Very sweet</td>
<td>Very good</td>
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<tr>
<td>FHIA-03</td>
<td>Good</td>
<td>Very good</td>
<td>Very sweet</td>
<td>Fairly dry</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>Very good</td>
<td>Very good</td>
<td>Sweet</td>
<td>Fairly dry</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>Good</td>
<td>Very good</td>
<td>Sweet</td>
<td>Fairly dry</td>
</tr>
</tbody>
</table>

- The processing potential of the introduced cultivars was evaluated. Based on their initial findings, FHIA-23 was found good for making catsup and FHIA-21 for making chips.
- Another set of planting materials were already in the farmer’s field. Data collection is still in progress.

LOA 2003/09 QSC, Diffun, Quirino/Dr Biley Temanel
- In 2003 and 2004, some 12,373 meriplants comprising of FHIA-03, FHIA-18, FHIA-23, FHIA-25, ‘Lakatan’, and ‘Bungulan’, were distributed in three batches.
Table 7. Agronomic characteristics of the introduced banana cultivars in Cavite, Philippines, 2004.

<table>
<thead>
<tr>
<th>Ecological zone/ soil type</th>
<th>Location/ Variety</th>
<th>Date planted</th>
<th>Planting to shooting (days)</th>
<th>Height of sucker (cm)</th>
<th>Height of pseudo-stem (cm)</th>
<th>Girth of pseudo-stem (cm)</th>
<th>No. of functional leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland flat</td>
<td>FHIA-03</td>
<td>17 June 2003</td>
<td>367</td>
<td>0.68</td>
<td>1.65</td>
<td>39.6</td>
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<td></td>
<td>FHIA-21</td>
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<td>345</td>
<td>0.58</td>
<td>1.44</td>
<td>41.8</td>
<td>5.50</td>
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<tr>
<td></td>
<td>FHIA-23</td>
<td></td>
<td>398</td>
<td>0.54</td>
<td>1.37</td>
<td>37.0</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td></td>
<td>340</td>
<td>0.97</td>
<td>1.47</td>
<td>39.8</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td></td>
<td>364</td>
<td>1.17</td>
<td>1.59</td>
<td>42.0</td>
<td>5.50</td>
</tr>
<tr>
<td>Upland hilly</td>
<td>FHIA-03</td>
<td>17 June 2003</td>
<td>329</td>
<td>1.79</td>
<td>2.83</td>
<td>73.0</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>FHIA-21</td>
<td></td>
<td>369</td>
<td>1.48</td>
<td>2.52</td>
<td>51.4</td>
<td>8.00</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td></td>
<td>310</td>
<td>2.12</td>
<td>2.92</td>
<td>70.8</td>
<td>8.20</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td></td>
<td>312</td>
<td>2.03</td>
<td>2.41</td>
<td>55.6</td>
<td>6.20</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td></td>
<td>362</td>
<td>1.34</td>
<td>2.44</td>
<td>49.8</td>
<td>6.80</td>
</tr>
<tr>
<td>Lowland irrigated</td>
<td>FHIA-03</td>
<td>23 May 2003</td>
<td>301</td>
<td>1.72</td>
<td>2.81</td>
<td>66.7</td>
<td>7.48</td>
</tr>
<tr>
<td>CvSU demo plot</td>
<td>FHIA-21</td>
<td></td>
<td>328</td>
<td>1.78</td>
<td>3.80</td>
<td>69.0</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td></td>
<td>274</td>
<td>1.14</td>
<td>1.97</td>
<td>48.2</td>
<td>6.35</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td></td>
<td>353</td>
<td>1.57</td>
<td>2.69</td>
<td>52.5</td>
<td>5.51</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td></td>
<td>336</td>
<td>1.08</td>
<td>2.16</td>
<td>43.7</td>
<td>7.00</td>
</tr>
</tbody>
</table>

Table 8. Agronomic characteristics of introduced banana cultivars at harvest in Cavite, Philippines, 2004.

<table>
<thead>
<tr>
<th>Ecological zone/ soil type</th>
<th>Location/ Variety</th>
<th>Bunch weight (kg)</th>
<th>No. of hands/ bunch</th>
<th>No. of fruits</th>
<th>Weight of fruit (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland flat</td>
<td>FHIA-03</td>
<td>6.67</td>
<td>5.30</td>
<td>55.60</td>
<td>99.96</td>
</tr>
<tr>
<td></td>
<td>FHIA-21</td>
<td>6.36</td>
<td>5.60</td>
<td>55.60</td>
<td>95.65</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td>6.51</td>
<td>5.50</td>
<td>47.50</td>
<td>117.61</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td>6.60</td>
<td>5.20</td>
<td>45.40</td>
<td>118.72</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td>5.95</td>
<td>6.00</td>
<td>55.75</td>
<td>88.39</td>
</tr>
<tr>
<td>Upland hilly</td>
<td>FHIA-03</td>
<td>10.43</td>
<td>8.30</td>
<td>105.20</td>
<td>89.78</td>
</tr>
<tr>
<td></td>
<td>FHIA-21</td>
<td>10.74</td>
<td>7.60</td>
<td>81.70</td>
<td>119.41</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td>13.70</td>
<td>9.11</td>
<td>108.00</td>
<td>122.06</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td>10.98</td>
<td>7.80</td>
<td>81.40</td>
<td>122.06</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td>10.36</td>
<td>7.86</td>
<td>90.86</td>
<td>101.92</td>
</tr>
<tr>
<td>Lowland irrigated</td>
<td>FHIA-03</td>
<td>8.25</td>
<td>7.02</td>
<td>79.85</td>
<td>91.50</td>
</tr>
<tr>
<td>CvSU demo plot</td>
<td>FHIA-21</td>
<td>16.27</td>
<td>10.51</td>
<td>132.50</td>
<td>152.97</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td>13.39</td>
<td>8.26</td>
<td>114.40</td>
<td>108.21</td>
</tr>
<tr>
<td></td>
<td>'Lakatan'</td>
<td>9.01</td>
<td>7.20</td>
<td>84.60</td>
<td>108.45</td>
</tr>
<tr>
<td></td>
<td>'Bungulan'</td>
<td>8.15</td>
<td>5.91</td>
<td>69.88</td>
<td>104.12</td>
</tr>
</tbody>
</table>

- The farmer cooperators were selected in four agro-ecological zones: lowland rainfed, lowland irrigated, upland plain and upland hilly.
- The crops are now in their fruiting stage. FHIA-18 was observed to be the earliest to mature. Data are still being consolidated. However, the project has indicated that the early harvested fruits of FHIA-18, in combination with ‘Bungulan’ fruits, showed promising acceptance for making banana cakes.
- Data collection was still not completed.
LOA 2003 ISPSC, Sta Maria, Ilocos Norte/Ms Elena Ato

- 1586 meriplants of FHIA-03, FHIA-18, FHIA-23, FHIA-25, ‘Bungulan’ and ‘Lakatan’ were distributed to the farmer-cooperators under different agro-ecological zones.
- Two planting sites were located in the school’s two campuses: one in Sta. Maria and the other in Cervantes. Eleven sites were in farmers’ fields located in nine towns of Ilocos Sur.
- The plants were still on their early vegetative stage.
- Initially, no pest infestation was observed in most test sites, except in one area where leaf rolling insects were observed.

LOA 2003 Virlanie Foundation Inc./Mr Telesforo Caminsi

- A total of 1750 meriplants of FHIA-18, FHIA-23, FHIA-25, ‘Lakatan’ and ‘Latundan’ were planted under upland hilly area conditions in Balayan, Batangas.
- Initial data collected are summarized in Tables 9 and 10. The data were gathered on early-bearing trees (2–3 trees per variety). FHIA-23 generated shoots and bore fruits the earliest. FHIA-25 had no fruit-bearing plants during the initial data collection.
- It was observed that ‘Lakatan’ was susceptible to BBTV and sigatoka while FHIA-23 was the most tolerant among the cultivars planted.

### Table 9. Agronomic characters of introduced and local banana cultivars grown in Balayan, Batangas, 2004.

<table>
<thead>
<tr>
<th>Ecological zone/soil type</th>
<th>Location/ Variety</th>
<th>Date planted</th>
<th>Planting to shooting (days)</th>
<th>Height of sucker (cm)</th>
<th>Height of pseudo-stem (cm)</th>
<th>Girth of pseudo-stem (cm)</th>
<th>No. of functional leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland hilly</td>
<td>‘Lakatan’</td>
<td>20 Sept. 2003</td>
<td>374</td>
<td>116.33</td>
<td>260</td>
<td>51</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>FHIA-18</td>
<td>11 Aug. 2003</td>
<td>392</td>
<td>92.33</td>
<td>178</td>
<td>44</td>
<td>7.6</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td>11 Aug. 2003</td>
<td>384</td>
<td>123.66</td>
<td>256</td>
<td>48</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>‘Bungulan’</td>
<td>11 Aug. 2003</td>
<td>396</td>
<td>122.00</td>
<td>190</td>
<td>46</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>FHIA-25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ecological zone/soil type</th>
<th>Location/ variety</th>
<th>Bunch weight (kg)</th>
<th>No. of hands/bunch</th>
<th>No. of fruits</th>
<th>Weight of fruit (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upland hilly</td>
<td>‘Lakatan’</td>
<td>15.68</td>
<td>6.3</td>
<td>91.33</td>
<td>145.0</td>
</tr>
<tr>
<td></td>
<td>FHIA-18</td>
<td>10.41</td>
<td>6.0</td>
<td>68.33</td>
<td>152.3</td>
</tr>
<tr>
<td></td>
<td>FHIA-23</td>
<td>15.68</td>
<td>6.3</td>
<td>84.33</td>
<td>169.0</td>
</tr>
<tr>
<td></td>
<td>‘Bungulan’</td>
<td>8.30</td>
<td>5.0</td>
<td>54.00</td>
<td>153.0</td>
</tr>
<tr>
<td></td>
<td>FHIA-25</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 10. Initial yield attributes of introduced and local banana cultivars grown in Balayan, Batangas, 2004.
LOA 2003 SLPC, Lucban, Quezon/Dr Wenceslao Durante
- About 2500 meriplants of FHIA-18, FHIA-23, FHIA-25, ‘Bungulan’ and ‘Lakatan’ were distributed to the farmer-cooperators selected from different agro-ecological zones: upland hilly, upland plain, lowland rainfed and lowland irrigated.
- Based on the initial observation, plants in the lowland areas were well-maintained and exhibited superior growth. However, in the upland areas, plants suffered from water stress and their growth was stunted.
- In terms of pest and disease management, appropriate actions were undertaken to eliminate the attack of insect pests and diseases. Initially, only one introduced cultivar was found to be infected with BBTV in one of the test sites. Leaf spot and freckles were observed in most test sites but reaction of the different cultivars varied. Most introduced varieties were less infected with Sigatoka, while ‘Lakatan’ showed higher susceptibility.
- Data collection will be completed by the first quarter of 2005.

LOA 2004 MinSCAT, Alcate, Oriental Mindoro/Dr Concepcion Mores
- About 5000 meriplants of FHIA-18, FHIA-23, FHIA-25, ‘Lakatan’ and ‘Bungulan’ were still being maintained in the station nursery.

LOA 2004 PAC/Prof. Virgilio Bagunu
- About 6000 meriplants of FHIA-18, FHIA-23, FHIA-25, ‘Lakatan’ and ‘Bungulan’ were still being reared in the nursery.

Biotechnology-assisted development of banana bunchy top virus resistance in banana by mutation breeding
OP Damasco, TO Dizon, FC de la Cruz, R Rabara, JB Estrella compose the team of this IPB-UPLB/DOST-PCARRD-funded project.
- A total of 6012 plants generated from gamma-irradiation treatments were screened for resistance to BBTV using artificial inoculation of the virus by aphid transmission. Indexing for BBTV was done using symptomatology and ELISA technique.
- Of the 6012 plants screened in the greenhouse, 114 plants which were without symptoms of BBTV were selected after 9 months of evaluation. These plants were planted in the field to evaluate their agronomic characters and confirm their resistant reaction to BBTV.
- To date, 64 putative BBTV resistant lines (M1 plants) have been selected from the field. These putative lines exhibited varying degrees of resistance reaction to BBTV. Twenty-six lines showed
no BBTV symptom expression in both irradiated plants (M1) and first-generation sucker plants; 21 lines were without BBTV symptom expression in M1 plants but with limited BBTV symptoms such as narrowing and yellowing of leaves, in some first generation sucker plants; 16 lines showed delayed and limited symptom expression in both M1 and first generation sucker plants. All suckers from the putative resistant lines were collected, multiplied in vitro, and will be planted in the field for a second-cycle confirmation of BBTV resistance.

- All the putative resistant plants produced fruits. The yield and horticultural characteristics of some of the putative lines were comparable with the non-irradiated micro-propagated plants.
- Nine hundred plants from 30 putative resistant lines were planted in the field for second-generation field evaluation. The remaining 34 putative resistant lines are being established in the greenhouse (19 lines) or are in varying stages of micropropagation (15 lines). Duplicates of 64 putative resistant lines are being maintained in vitro.

**Development of banana varieties resistant to BBTV by genetic engineering**

VM Aquino, OP Damasco, TO Dizon, and GR Canama of IPB-UPLB are conducting the project.

- BBTV-CP DNA was amplified from BBTV isolates using the CPL and CPR primers. PCR amplification of total nucleic acid extracts generated a 589 bp product in young leaves of IPB samples. One gene construct (BBTV-CP-DNA) was developed by cloning the coat protein (cp) of BBTV into a transformation vector.
- Compact and embryogenic calli were initiated from 355 immature male inflorescence explants of banana using MS medium with varying amounts of 2, 4-D (1-4 mg/L) with and without BAP (1-5 mg/L). Plantlet regeneration was observed on both compact and friable calli. Embryonic calli and somatic embryos were maintained by regular subculture and were used for transformation work.
- Transformation of embryogenic calli with the BBTV cp gene, using the optimized bombardment parameters, was undertaken. Bombarded calli are now in the selection and regeneration medium.
- The cp gene was introduced into somatic embryos and meristems of banana using Agrobacterium-mediated transformation.
**S&T Anchor Programme for Banana**

CvSU, DMMMSU and QSC are the proponents of this UPLB/DOST-PCARRD-funded project.

This programme aims to improve the productivity and socioeconomic welfare of the smallholder banana growers of ‘Saba’, ‘Lakatan’ and ‘Latundan’ in selected banana-growing areas. The initial projects to be conducted starting November 2004 are as follows:

- **Project 1.1. Development of management strategies against major diseases of ‘Saba’, ‘Lakatan’ and ‘Latundan’/ funded by CvSU, DMMMSU, and QSC/ DOST-PCARRD-INIBAP**

  This project will develop integrated pest management (IPM) strategies for the three cultivars. Cropping system and cultivar diversity, in combination with proper sanitation/rouging, deleafing, use of disease-free planting materials, and chemical control, will be evaluated as a means of assessing disease occurrence and severity.

- **Project 2.1. Technology assessment of new banana technologies/ funded by TOPD-PCARRD/ DOST-PCARRD**

  This project will employ the Technology Assessment Protocol in evaluating the appropriate technologies that will be further promoted in farmers’ fields. The following are the technologies to be assessed: 1) disease-free planting materials for the smallholder growers; 2) new cultivars of banana; 3) banana cropping systems under coconut; 4) improved management system for ‘Saba’ Bugtok IPM and improved production system of ‘Saba’; and 5) new processed ‘Saba’ products.

- **Project 3.2. Analysis and advocacy of policy options to enhance the development of the Philippines’ smallholder banana sub-industry/ funded by SERD-PCARRD/DOST-PCARRD**

  This project aims to come up with a set of policy options/recommendations from the policy research/analysis. Incorporated within these policy options are the reforms and interventions that should be put in place as a result of the evaluation of the policies in terms of its letter of intent and of its implementation and effects on the development of the sub-industry.

- **Project 3.5. Analysis of the marketing efficiency and development of innovative marketing strategies for the smallholder banana growers/ funded by UPLB-CEM/DOST-PCARRD**

  This project will make use of data gathered from primary and secondary sources. Primary sources of information will be the surveys and case studies of farmers, processors, and traders in
selected banana-producing provinces (Regions 1, 2, and 4). Published and unpublished reports will be reviewed to provide an initial assessment of the banana production-marketing-consumption system. Existing strategies and modalities for marketing agricultural products will be analyzed. Among these strategies are marketing by producer groups (e.g., cooperatives, and informal and formal farmers’ organizations) and shortening the marketing chain (e.g., partnerships among producer groups and business firms).

### Capacity-building activities in 2004

<table>
<thead>
<tr>
<th>Title of training/ workshop/meeting</th>
<th>Sponsors</th>
<th>Venue/Date</th>
<th>Number of participants</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana R&amp;D Annual Review and Planning Meeting</td>
<td>VVOB/INIBAP/PCARRD/DA-BAR</td>
<td>PCARRD, Los Baños, Laguna</td>
<td>21</td>
<td>Project leaders and staff Coordinating committee members</td>
</tr>
<tr>
<td>Training on Banana Disease Management &amp; Data Collection</td>
<td>VVOB/INIBAP/PCARRD/DA-BAR</td>
<td>PCARRD, Los Baños, Laguna</td>
<td>26</td>
<td>Project leaders and staff Ag. Technicians</td>
</tr>
<tr>
<td>Training on Nursery and Field Management of Tissue Cultured Banana Plantlets (2)</td>
<td>VVOB/INIBAP/PCARRD</td>
<td>Pampanga Agricultural College, Magalang, Pampanga/ 18–19 May 2004</td>
<td>18</td>
<td>Project leaders and staff Ag. Technicians Farmer Cooperators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mindoro State College of Agriculture and Technology, Alcante, Mindoro Occidental/ 25–26 May 2004</td>
<td>33</td>
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<tr>
<td>International Workshop on Sustainable Production through the Use of Healthy Seedlings</td>
<td>FFTC/INIBAP</td>
<td>Palace Hotel, Ho Chi Minh City, Viet Nam/ 4–8 October 2004</td>
<td>2</td>
<td>Project staff and coordinator from the Philippines</td>
</tr>
</tbody>
</table>

### Other activities

- A Letter of Agreement (LOA) on Banana R&D Collaborative Project was signed on 15 March 2004 at PCARRD, Los Baños, Laguna by presidents and representatives of collaborating SUCs (DMMMSU, QSC, CvSU, SLPC, MinSCAT, PAC, and ISPSC), heads of agencies (PCARRD and DA-BAR), regional coordinators and staff of INIBAP, director and staff (CRD-PCARRD), and the media core group.
- *A Banana Production Manual*, prepared by PCARRD was released.
- The HORTINET Website under the PCARRD Information System. HORTINET contains information about various horticultural commodities, including banana was updated.
Banana in Sri Lanka: Status and Prospects

Chandrasiri Kudagamage*

Introduction

Banana is the most important fruit crop in Sri Lanka in terms of hectarage, production and consumption. The area of banana cultivated in 2003 showed a slight increase over the year 2002. The increase is mainly due to the newly established commercial scale production units in the country. However, the production did not show a similar trend (Table 1).

Table 1. Comparison of hectarage, production and export of banana.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ha)</td>
<td>47 850</td>
<td>49 255</td>
</tr>
<tr>
<td>Production (t)</td>
<td>380 628</td>
<td>393 384</td>
</tr>
<tr>
<td>Exports (t)</td>
<td>7.16</td>
<td>5.89</td>
</tr>
</tbody>
</table>

Government policy

According to policy guidelines outlined by the government of Sri Lanka, agriculture research will be more focused to address the issues of productivity, crop yield and quality, superior varieties, economic efficiency of agronomic practices, sustainability of agriculture, management of markets and external issues. Both local development and introduction of superior varieties subjected to plant protection regulations is envisaged. The operational diagnostic indexing of imported planting material will be further strengthened. Provision of improved varieties and high-quality planting materials in sufficient quantities and at competitive prices is a necessary requirement to raise the crop productivity and income of the farmer. The capacity of government farms for producing planting materials will be strengthened to create competitiveness with the private sector which has a major share in the production of planting material. A major goal of the present agricultural plan is to raise the farming capability of the peasant farmers through the mobilization of farmers through the formation of farmer societies (FS) and empowerment of them with technical knowledge, marketing capabilities, investment capacity and bargaining power.

*Director, HORDI, Gannoruwa, Peradeniya, Sri Lanka.
Shortage of trained extension personnel at village level and the lack of modernity in the extension and technology transfer system are the constraints to the delivery of extension services and technology in effective manner. The work plan developed for the next 5 years suggests two strategies: first extension and technology at village level to take place through FS assisted by extension staff at central and provincial level and second to modernize extension and technology delivery through the utilization of state–of–the–art technology based on cyber extension.

**Current R&D projects**

The bulk of the research and development of banana is conducted by the Department of Agriculture (DOA). The other institutions involved are Institute of Postharvest Technology, Faculties of Agricultural Sciences of different Universities, Department of Plant Science of University of Colombo, Department of Botany, Kelaniya University and Industrial Technology Institute.

The research programme of DOA is based on six thematic areas;
1. Production of disease-free planting material
2. Characterization, evaluation of banana germplasm and development of varieties
3. Management of banana pests and diseases through environmentally compatible methods
4. Productivity improvement through better agronomic and irrigation methods
5. Soil nutrient management for different banana growing areas
6. Causal factors and management of internal browning of banana.

The various projects/programmes undertaken in each thematic area are presented in Table 2.

**Progress of germplasm evaluation under International *Musa* Testing Programme (IMTP)**

Several varieties obtained from IMTP since 1999 after the commencement of the programme were evaluated at Regional Research Station, Angunakolapellessa. The promising two varieties FHIA-17 and FHIA-23 were subjected to multilocal testing at Angunakolapellessa (Dry Zone), Ginnadurukotte (Intermediate Zone) and Weerapana (Wet Zone). FHIA-17 and FHIA-23 showed promising results of higher bunch weight and good adaptability (Table 3 and Table 4). The two varieties did not show any leaf disorders. However, there was high incidence of stem weevil at Angunakolapellessa.
Table 2. Current R&D projects of banana in Sri Lanka.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Title of the research</th>
<th>Name of researcher</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Production of disease-free planting material</td>
<td>Maintenance of banana germplasm by tissue culture</td>
<td>D.P. Prematilake</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Protocol optimization for tissue culture</td>
<td>D.P. Prematilake</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Field testing of tissue-culture planting material</td>
<td>D.P. Prematilake</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Multiplication of basic planting material</td>
<td>S.M. Nagahawatta</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Tissue culture propagation of virus free planting material</td>
<td>S. Vaheesan &amp; V.G.S. Perera</td>
<td>PVC, Gabadawatta</td>
</tr>
<tr>
<td>2. Characterization and evaluation of banana germplasm and development of varieties</td>
<td>Germplasm evaluation and selection</td>
<td>A.J. Warunsawitharana</td>
<td>FCRDC, Horana</td>
</tr>
<tr>
<td></td>
<td>Molecular characterization</td>
<td>E.M.D.S.N. Ekanyake, W.G.B. Samaranasinghe</td>
<td>PGRC</td>
</tr>
<tr>
<td></td>
<td>Multiplication of nuclear planting material</td>
<td>S. Weerasinghe</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Germplasm evaluation</td>
<td>S. Weerasinghe</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Identification of different strains of banana streak virus by molecular methods</td>
<td>E.M. Dissanayaaye</td>
<td>HORDI</td>
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<td>Heat therapy to eradicate banana bract mosaic virus in Embul banana</td>
<td>I. Ariyaratne</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Identification and management of insect vectors of banana bract mosaic and streak virus</td>
<td>I. Wahundeniya</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Survey of leaf diseases of banana</td>
<td>R.G.A.S. Rajapaksa</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Studies of biological control and varietal vectors of banana bract mosaic and streak virus</td>
<td>R.G.A.S. Rajapaksa</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Temporal distribution of banana weevil</td>
<td>S.M.C. Subasinghe</td>
<td>HORDI</td>
</tr>
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<td></td>
<td>Insecticidal control of banana weevil</td>
<td>L.C. Wijetilake</td>
<td>RARDC, Makandura</td>
</tr>
<tr>
<td></td>
<td>Development of management package of Sigatoka leaf disease in the wet zone</td>
<td>P.W. Alahakoon</td>
<td>FCRDC, Horana</td>
</tr>
<tr>
<td>4. Productivity improvement through better agronomic and irrigation methods</td>
<td>Yield evaluation under high-density planting</td>
<td>S.M. Bandana</td>
<td>ARS, Girandurukotte</td>
</tr>
<tr>
<td></td>
<td>Soil nutrients on postharvest diseases</td>
<td>K.H. Sarananada</td>
<td>FRU, Gannoruwa</td>
</tr>
<tr>
<td></td>
<td>Adaptability testing for high-density banana in NCB soil</td>
<td>I.K. Warshamana</td>
<td>RARDC, Angulapannela</td>
</tr>
<tr>
<td></td>
<td>Status of rain-fed banana cultivation in southern dry zone</td>
<td>W.A.K.</td>
<td>RARDC</td>
</tr>
<tr>
<td></td>
<td>Evaluation of different irrigation regimes on two banana varieties</td>
<td>Karunathilaka</td>
<td>Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M.A. Rooneage</td>
<td>NRMC</td>
</tr>
<tr>
<td>5. Soil nutrient management for different banana growing areas</td>
<td>Development of nutrient management package for mid country of Sri Lanka</td>
<td>J.M.P.B. Jayasundara</td>
<td>HORDI</td>
</tr>
<tr>
<td></td>
<td>Influence of N &amp; K on growth and yield of banana</td>
<td>P. Weerasinghe</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Utilization of high-grade Eppawala rock phosphate for banana instead of rock phosphate</td>
<td>S.D.R. Wanniarachchi</td>
<td>FCRDC, Horana</td>
</tr>
<tr>
<td>6. Causal factors and management of internal browning of banana</td>
<td>Influence of Ca on the development of internal browning syndrome of banana</td>
<td>P. Weerasinghe</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Effect of boron and calcium on internal browning of banana</td>
<td>S.D.R. Wanniarachchi</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Investigation of internal browning of banana</td>
<td>J.S. Weerasinghe</td>
<td>RARDC, Angunakolapelessa</td>
</tr>
<tr>
<td></td>
<td>Investigation of causal factors of internal browning</td>
<td>L.C. Wijetilaka</td>
<td>RARDC, Makandura</td>
</tr>
</tbody>
</table>

FHIA-03 and SH-3640 were released by the varietal recommendation committee of the Department of Agriculture (Local Name Pulathesi and Kandula, respectively) in 2001. These varieties are presently being multiplied conventionally and through tissue culture in both state and private tissue-culture laboratories. These varieties have high yield and

<table>
<thead>
<tr>
<th>Variety</th>
<th>Maturity age (days)</th>
<th>Bunch weight (kg)</th>
<th>Finger weight (g)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; bunch</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; bunch</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; bunch</td>
</tr>
<tr>
<td>SH-3640</td>
<td>200</td>
<td>25.5</td>
<td>22.6</td>
<td>25.8</td>
</tr>
<tr>
<td>FHIA-01</td>
<td>210</td>
<td>23.3</td>
<td>22.1</td>
<td>22.4</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>210</td>
<td>14.5</td>
<td>13.7</td>
<td>10.2</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>210</td>
<td>26.4</td>
<td>27.8</td>
<td>25.3</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>258</td>
<td>25.4</td>
<td>22.4</td>
<td>14.2</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>240</td>
<td>18.8</td>
<td>17.1</td>
<td>16.6</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>210</td>
<td>15.5</td>
<td>13.6</td>
<td>13.5</td>
</tr>
<tr>
<td>Grande</td>
<td>185</td>
<td>15.3</td>
<td>11.2</td>
<td>12.6</td>
</tr>
<tr>
<td>Naine</td>
<td>450</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yangambi</td>
<td>450</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Km 05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Highly susceptible for CMV

Table 4. Yield performance of two pipeline varieties at different locations in an adaptability-testing trial conducted in 2003–2004.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield – bunch weight (kg) in different locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry zone</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>38</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>22</td>
</tr>
</tbody>
</table>

are resistant to leaf diseases. FHIA-03 possesses favourable processing values for the preparation of banana crisps. However, since the taste of fresh fruits of these varieties does not confirm to the taste of people, presently, there is no demand for their planting material.

**Highlights of research during the year**

Banana is generally grown as a mixed crop in either backyard or as a monocrop in small- (1.2 ha) to medium-sized (10-50 ha) commercial plantations. Most of the commercial plantations are confined to dry zone of the country. Inter cultivation of banana with plantation crops like rubber is not common. A participatory farming system research conducted by the Rubber Research Institute of Sri Lanka has revealed that intercropping of rubber with two rows of banana between two rubber rows does not have deleterious effects on either crop. Intercropping was a practical measure to generate income during the early stages of rubber cultivation particularly in the intermediate zone where farmers depend more on farm income than off-farm activities (Rodrigo et al. 2003).

A study was conducted to investigate influence of nitrogen fertilizer on the growth and yield of silk banana in a dense planted system (3 m × 1 m). Application of nitrogen at 2-month interval at the rate of N per plant increased the number if fingers per hand and also the
finger weight. Results further revealed that it is necessary to maintain the nitrogen content of the third youngest leaf (lamina 3) greater than 3.0% at the late vegetative stage to obtain good yield (Weerasinghe et al. 2004).

Among the cultural measures to increase the quality of banana de-handing or bunch trimming resulted in more uniform fruits having higher fruit length, girth and weight in ‘Ambul’ (Mysore), ‘Kolikuttu’ (Silk) and Ash Plantain (Weerasinghe and Ruwanpathirane 2004).

Anthracnose caused by *Collectotrichum musae* and crown rot caused by *Lasiodiplodia theobromae*, *Collectotrichum musae*, *Fusarium* species and *Verticillium theobromae* are important postharvest diseases of banana which affect the quality of banana available for export and local market (Anthony et al. 2004). To prevent crown rot and anthracnose bananas are universally treated with systemic fungicide such as benomyl, a possible human carcinogen and teratogen. Studies have shown essential oil of *Cymbopogon nardus*, *Cymbopogon flexuosus* and *Ocimum basilicum* to possess significant microbial properties. Fumigant bioassay developed by Abeywicrama et al. (2003) is a valuable tool to identify the efficacy of plant oils, before in vitro testing is conducted. In subsequent studies, spraying of essential oils of *Ocimum basilicum* (0.16% v/v) prior to cool storage was found to be a safe, cost-effective method with commercial potential for controlling postharvest diseases and extending storage life.

**Marketing of banana**

The private sector plays a dominant role in the marketing of banana. Wholesale marketing centres of banana are located in different parts of the country. At these centres, collectors/farmers sell their products to wholesalers, who in turn sell them to retailers. There is a certain amount of grading in these centres, however there are high postharvest losses due to bad handling and transport.

There are five varieties of banana in the market namely, ‘Ambul’ (Mysore), Ambun (Cavendish), ‘Kolikuttu’ (Silk), ‘Seen’ and ‘Anamalu.’ ‘Embul’ and ‘Seen’ are cheaper than others (Table 5).

**Table 5. Prices of banana in 2002-2003. (Rs/fruit)**

<table>
<thead>
<tr>
<th>Variety</th>
<th>2003 Farm gate price</th>
<th>2002 Wholesale</th>
<th>Retail</th>
<th>2003 Wholesale</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Ambul’ (Mysore)</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>‘Kolikuttu’ (Silk)</td>
<td>0.03</td>
<td>0.05</td>
<td>0.08</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>‘Seen’</td>
<td>-</td>
<td>0.01</td>
<td>0.02</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>‘Anamalu’ (Cavendish)</td>
<td>-</td>
<td>0.04</td>
<td>0.07</td>
<td>0.05</td>
<td>0.07</td>
</tr>
<tr>
<td>‘Ambun’ (Cavendish)</td>
<td>-</td>
<td>0.05</td>
<td>0.07</td>
<td>0.51</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Advancing banana and plantain R&D in Asia and the Pacific - Vol 13

Capacity building

DOA undertakes major training and capacity development programmes through their In-Service Training Institutes. Banana is given high priority in the curriculum of the training programme of the pre-seasonal training courses arranged twice a year.

A training workshop on Banana Disease Identification and Healthy Planting Materials Production was held in 2004. for researchers, extensionists and development specialists of various research institutions, universities and private sector institutions involved in banana R&D. The highlight of the event is the participation of Dr A.B. Molina, regional coordinator of INIBAP, Prof H.J. Su, plant virologist, and Dr S.C. Hwang, consultant of the Taiwan Banana Research Institute, as resource persons. At the end of the workshop, a programme for the development of healthy planting materials was developed by the participants with the assistance from the experts.

Publications


Comparison of *Musa* germplasm in Thailand

S. Chandraparnik*, C. Ditchaiwong and K. Bansiddhi

Banana plays a major role in food security and income generation of the region’s rural poor. It is a good source of energy, vitamins and minerals, thus making it a nutritious staple food. The fruits are mostly produced for domestic consumption, although a number of fresh fruits and processed products are exported to various countries. The export value per annum is approximately $3.7M.

Objectives

1. To maintain and distribute *Musa* germplasm in Thailand
2. To select *Musa* germplasm for high yield and high quality.

Maintenance and distribution of *Musa* germplasm

In Thailand, apart from fresh consumption and processed product uses, the other parts of banana are also utilized in many Thai cultural and traditional activities. The total banana cultivation is 10 M ha, and this is comprised of smallholdings. Approximately 50 different varieties are being planted but only three are cited as economic fruits for their distinctive features and taste. These are ‘Kluai Namwa’ (ABB), ‘Kluai Hom’ (AAA) and ‘Kluai Khai’ (AA). In 2004, the estimated cultivated areas for these varieties is 161 573 ha.

Comparison of *Musa* germplasm

The project ‘Comparison of *Musa* germplasm in Thailand’ was introduced by INIBAP in 21 February 2003 as a collaboration between the Horticulture Research Institute (HRI) of the Department of Agriculture (DA) and INIBAP. This project was carried out in the PhiChit Horticultural Research Center of DA. Twenty-three in vitro banana accessions were received in February 2003 from INIBAP ITC. These were cultured for plant multiplication in the Murashige and Skoog (MS) medium. Of the 23 accessions, FHIA-18 was contaminated and died later on. Other accessions were transferred in the greenhouse of PHRC. The healthy young plants of the 22 accessions were selected and grown in the field of PHRC from September 2003 to November 2004.

*Director, Horticulture Research Institute, Department of Agriculture Chatuchak, Bangkok 10900 Thailand.*
Randomized complete block design (RCBD) with two replications was used. Data were recorded such as number of days from planting to harvest, bunch weight, number of hands in bunch after harvest, number of fingers per hand, number of functional leaves at harvest (a leaf is functional if it has more than 50% of the green area) and sigatoka severity scoring. Currently 10 of the 22 accessions have been harvested from June to October 2004. These are P. Jari Buaya’, FHIA-02, ‘Williams’, ‘AA cv Rose’, FHIA-17, TMBx5295, FHIA-21, CRBP 39, ‘P. Ceylan’ and GCTV-247.

The results are as follows:

- Number of days from planting to flowering ranged from 175 to 240 days. ‘Williams’ was the earliest accession to flower at 175 days after planting while FHIA-17 took the longest at 240 days (Table 1).
- Number of days from flowering to harvest ranged from 91 to 124 days. ‘P. Jari Buaya’ was the earliest accession to be harvested at 91 days while it took 124 days for ‘Williams’ to flower (Table 1).
- Plant height after planting to harvest ranged from 1.60 to 3.08 m. ‘AA cv Rose’ was the shortest at 1.67. TMBx5295 had the highest plant height at 3.08 m (Table 1).

<table>
<thead>
<tr>
<th>Cultivar name</th>
<th>Days from planting to flowering</th>
<th>Days after flowering to harvest</th>
<th>Plant height at harvest (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘P. Jari Buaya’</td>
<td>236</td>
<td>91</td>
<td>2.77</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>190</td>
<td>111</td>
<td>2.35</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>175</td>
<td>124</td>
<td>1.93</td>
</tr>
<tr>
<td>‘AA cv Rose’</td>
<td>195</td>
<td>115</td>
<td>1.60</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>240</td>
<td>99</td>
<td>3.08</td>
</tr>
<tr>
<td>TMBx5295</td>
<td>193</td>
<td>94</td>
<td>3.08</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>218</td>
<td>107</td>
<td>2.85</td>
</tr>
<tr>
<td>CRBP 39</td>
<td>183</td>
<td>112</td>
<td>2.85</td>
</tr>
<tr>
<td>‘P. Ceylan’</td>
<td>209</td>
<td>108</td>
<td>2.89</td>
</tr>
<tr>
<td>GCTV-247</td>
<td>193</td>
<td>102</td>
<td>2.50</td>
</tr>
</tbody>
</table>

**Bunch weight** ranged from 3.68 to 31.69 kg. ITC codes ‘Williams’ and GCTV-247 had the highest bunch weight at 31.69 and 28.76 kg, respectively. The lowest bunch weight was recorded from ‘AA cv Rose’ at 3.68 kg (Table 2).

**Number of hands per bunch** ranged from 7 to 12 hands. The accession with the most number of hands per bunch was FHIA-17 with 12 hands per bunch while CRBP 39 and TMBx5295 with 7 hands per bunch had the lowest (Table 2).
Number of fingers per hand ranged from 12 to 21 fingers. ‘Williams’ had the highest number of fingers per hand at 21 fingers per hand while ‘AA cv Rose’ with had the lowest (Table 2).

Table 2. Fruit yield of *Musa* spp.

<table>
<thead>
<tr>
<th>Cultivar name</th>
<th>Bunch weight (kg)</th>
<th>Number of hands per bunch</th>
<th>Number of fingers per hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘P. Jari Buaya’</td>
<td>6.93</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>17.26</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>31.69</td>
<td>9</td>
<td>21</td>
</tr>
<tr>
<td>‘AA cv Rose’</td>
<td>3.68</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>17.34</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>TMxBx5295</td>
<td>16.67</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>20.26</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>CRBP 39</td>
<td>16.46</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>‘P. Ceylon’</td>
<td>13.71</td>
<td>11</td>
<td>17</td>
</tr>
<tr>
<td>GCTCV-247</td>
<td>28.76</td>
<td>9</td>
<td>16</td>
</tr>
</tbody>
</table>

Number of functional leaves at harvest ranged from 0 to 4 leaves per plant. ‘P.Ceylon’ gave the highest number of functional leaves at 4 leaves per plant. ‘Williams’, ‘AA cv Rose’, FHIA 17 and FHIA 21 had no functional leaves (Table 3).

Sigatoka severity scoring at harvest ranged from 1 to 3. FHIA-02 and CRBP 39 had the lowest score of 1 (<1% of lamina with symptoms). ‘Williams’ had the highest severity score of 5 (34 to 50% of lamina with symptoms) (Table 3).

Table 3. Number of functional leaves and sigatoka severity scoring at harvest time.

<table>
<thead>
<tr>
<th>Cultivar name</th>
<th>Number of functional leaves</th>
<th>Sigatoka severity scoring*</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘P. Jari Buaya’</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>‘AA cv Rose’</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>TMxBx5295</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>CRBP 39</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>‘P. Ceylon’</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>GCTCV-247</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* Legend: 0=no symptoms; 1=less than 1% of lamina with symptoms (only streaks and/or up to 10 spots); 2=1 to 5% of lamina with symptoms; 3=6-15% of lamina with symptoms; 4=16-33% of lamina with symptoms; 5=34 to 50% of lamina with symptoms; 6=51 to 100% of lamina with symptoms.
Data collection is still ongoing for the 12 other accessions. After completion, two accessions will be selected and will be compared and evaluated with local varieties in the farmers’ fields.
Current banana R&D in Vietnam

Ho Huu Nhi*

Vietnam stretches from 8°10’NL - 25°4NL in the Asia and the Pacific region, a region considered as the centre of origin of genus *Musa* (Gowen 1995) and therefore a rich source of diversity of banana. Banana has been grown for thousands of years in Vietnam. It is now one of the most important fruits growing in the country. Vietnam belongs to the 15 largest banana-producing countries of the world, with an annual production of 1 242 539 t. Its total cultivated area is estimated at 99 340 ha, next to longan (126 265 ha), litchi and rambutan (109 538 ha).

Vietnam is divided into six agro-ecological regions out of which Mekong Delta, Red River Delta and the Southeast regions are the major banana producing areas (Figure 1).

![Figure 1. Major banana producing areas in Vietnam.](image)

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*Head, Agro-biotechnology Department, VASI, Hanoi, Vietnam.
The banana cultivation is based on small-scale garden, usually surrounding the household, and on hillside. The common size of banana gardens ranges from 0.2-1.0 ha. Bananas are intercropped with other crops like maize, soybean, sweet potatoes or fruit trees. Compared with sole banana gardens, the productivity is lower in mixed banana gardens. The average yield is about 10-15 t/ha, depending on the region and the farmer’s cultivation level.

**The popular banana cultivars**

‘Chuoi Tieu’ (AAA/Gia). This Cavendish group consists of the most popular banana cultivars in Vietnam, which can be divided according to three different plant height; tall (2.8-3.5 m), medium (2.0-2.5 m) and dwarf (1.5-2.0 m). They are grown alongside rivers and highly humid areas. They give high yields of 20-25 kg/bunch, with 8-14 hands/bunch. Its fruit size is 2.8-3.5 cm. Ripened fruits are sweet and aromatic and have yellow skin and flesh. In the North, during the winter, the ripened fruits have a better quality compared with those grown in the South. Its growth duration is 14-15 months. ‘Chuoi Tieu’ is used for export and local market.

‘Chuoi Tay’ (ABB, Xiem) is planted throughout the country, from the delta to hilly regions. Its pseudostem is 3-4 m long. It gives high yield with 18-20 kg/bunch, 8-12 hands/bunch. The fruit size is 9-11 cm long and 3.0-3.5 in diameter. The ripe fruits have dark yellow skin and yellow, sweet and aromatic flesh. Sometimes, there are few seeds in the fruits. ‘Chuoi Tay’ is tolerant to drought and poor soil. ‘Chuoi Tay’ is used only for domestic consumption. They also can be eaten as fresh or processed as candies, cake, boil, etc.

‘Chuoi Ngu’ (AA, Cau) is one of the most preferred varieties because of its special characteristics. Pseudostem is 2.2-2.6 m long. Normally, its yields are 8-10 kg/bunch with 6-8 hands/bunch. The fruit size is 7-10 cm long and 2.5-3 cm in diameter. Ripened fruits have attractive bright yellow and pink, color and a sweet and aromatic flesh. The growth duration is 12 months.

‘Chuoi Ngu Tien’ (AA). In the olden days, this variety was used as precious donations to the kings which is why the variety was given the name Tien (donation- Dai Hoang). The fruit’s characteristics and growth duration are similar to those of ‘Chuoi Ngu’ but its fruits have a very attractive form and color and the flesh has better quality. Pseudostem is 1.5-2 m in height. These cultivars are grown nowadays in Nam Ha province.

‘Chuoi Bom’ (AAB) has a high tolerance to drought and is grown
popularly in the central highlands. It has a short growth duration (10-12 months) and high multiplication rate (8-10 suckers/plant). Its yield is 6-10 kg/bunch with 6-8 hand/bunch. Fruit size is 10-15 cm and 2-2.5 cm in diameter. Ripened fruits have bright yellow thin skin and yellow pink flesh, and are suitable for processing to make dried banana. These popular banana cultivars are shown in Figure 2 (Nhi 1997). There are some other cultivars such as Chuoi Com (AA), Chuoi Bot (AAB), Chuoi La (ABB), Chuoi Mat (AB), scattered over the different areas. These can be used as feed, cake draping etc.

Figure 2. Popular banana cultivars in Vietnam.

Banana research activities

Organizations involved in banana research work

The national banana network consists of many research institutions, laboratory and agricultural cooperative conducting different activities in their area of expertise.

- Vietnam Agricultural Science Institute (VASI), the National Repository, Multiplication and Distribution Centre, is incharge of conservation of *in-vitro* collection, its propagation and distribution for evaluation, testing and field trials.
- Southern Fruit Research Institute (SOFRI) conducts activities such as maintenance of a field collection, disease indexing, production of disease-free planting materials, field trials and postharvest technology.
- Fruit and Vegetable Institute (Gia Lam) established a procedure of banana micro-propagation, provides *in-vitro* plantlets to farmers, and implements trial for fusarium evaluation.
- Phu Ho Fruit Research Center maintains the national banana field collection.
- Institute of Biotechnology (IBT) applies molecular technique (RAPD, PCR etc.) in studying banana biodiversity and virus indexing.
• Tissue culture laboratories of provinces (Nghe An, Ha Nam) supply in vitro plantlets to farmers.
• Agricultural cooperatives carry out field trials of introduced and popular local cultivars.

At the same time, they coordinate many banana research projects funded by different donors. Table 1 shows the various research projects in 2003-2004 and their corresponding donors.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Projects</th>
<th>Donors</th>
</tr>
</thead>
<tbody>
<tr>
<td>VASI</td>
<td>Virus indexing; Farming technology; Establishing a repository</td>
<td>FFTC, TBRI INIBAP</td>
</tr>
<tr>
<td>SOFRI</td>
<td>Virus indexing; Setting up demonstration farm of TC-plantlets</td>
<td>FFTC, TBRI, CIRAD</td>
</tr>
<tr>
<td>IBT</td>
<td>Application of molecular technique in analyzing biodiversity and virus diagnostic of banana</td>
<td>MOST</td>
</tr>
<tr>
<td>Phu Ho Fruit Research Center</td>
<td>Ex-situ conservation of banana germplasm</td>
<td>Ministry of Agriculture and Rural Development</td>
</tr>
<tr>
<td>Tissue culture lab of Nghe An province</td>
<td>Application of tissue-culture technique in rapid multiplication of local banana for farmers</td>
<td>Ministry of Science and Technology</td>
</tr>
<tr>
<td>Science and Technology Dept. of Ha Nam province</td>
<td>In-situ conserving genetic resource of indigenous banana (Chuoi Tien)</td>
<td>NGO</td>
</tr>
</tbody>
</table>

**Banana collection and NRMDC**

The cooperative project “Collection, Characterization and Conservation of Musa Germplasm in Vietnam”, headed by Mr. Le Dinh Danh, ended in 1997. The project had established the national banana field collection with 80 accessions being maintained at Phu Ho Fruit Research Center. Banana collection consists of wild and cultivated groups:

1. **Wild and ornamental banana**
   - Chuoi Hot Rung: *Musa balbisiana* - Chuoi Rung
   - Chuoi Tay Rung: *M. acuminata* - Chuoi Rung Hoa Do
   - Chuoi Rung: *M. itinerans* - Chuoi Rung Hoa Sen
   - Chuoi Sen: *M. coccinea* - Chuoi Rung Hoa Xoan
   - M. laterita - Chuoi Cau Rung
   - Chuoi Nguon: *Ensete glaucum* - Chuoi Canh
2. Semi-wild, semi-cultivated banana
Chuoi Hot  *Musa balbisiana* with hard seed
Chuoi Hot Qua Lep  *Musa balbisiana* with soft seed

3. Edible cultivated banana with following genome:
AA (10), AAA (18), AAB (9), AB (10), ABB (13), BBB (3).

4. Introduced cultivars
To safeguard the banana germplasm of the country, duplicate field collection with 60 accessions was established in south Vietnam, at SOFRI (Phap and Chau 1995) (Table 2).

To further ensure the conservation of Vietnam’s indigenous *Musa* genetic resource, a duplicate *in-vitro* collection was also established at VASI with 80 accessions (Nhi 2004).

**Table 2.** Number of accessions of each genomic group.

<table>
<thead>
<tr>
<th>Genomic group</th>
<th>No. of accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ornamental group</td>
<td>7</td>
</tr>
<tr>
<td>2. Wild group</td>
<td></td>
</tr>
<tr>
<td>AAw</td>
<td>1</td>
</tr>
<tr>
<td>BBw</td>
<td>2</td>
</tr>
<tr>
<td>3. Cultivated group</td>
<td></td>
</tr>
<tr>
<td>AA</td>
<td>9</td>
</tr>
<tr>
<td>AAA</td>
<td>11</td>
</tr>
<tr>
<td>AAB</td>
<td>14</td>
</tr>
<tr>
<td>ABB</td>
<td>12</td>
</tr>
<tr>
<td>4. Unidentified</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>60</td>
</tr>
</tbody>
</table>

**NRMDC**
In 2001, VASI signed an agreement with INIBAP to establish a National Repository Multiplication and Distribution Centre. This centre undertakes activities in relation to receiving tissue-cultured materials from ITC, maintaining, multiplying and distributing them to users. From 2001 to 2003, VASI has received from ITC a total of 34 banana accessions. Among them, 5 accessions were lost and 29 were maintained *in vitro* under temperatures of 15-18°C and light intensity of 1200 lux with photoperiod of 14 h/day. Every 3 months, the *in vitro* accessions are sub-cultured. The procedure for maintenance, multiplication and distribution is shown in Table 3.
These banana accession introduced from ITC are maintained in vitro. From 2001 to 2004, VASI multiplied and distributed 21 accessions of the introduced cultivars for evaluation and field testing (Table 4).

**Table 3.** The procedure of in-vitro maintenance and distribution.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Culture medium</th>
<th>Environmental conditions</th>
<th>Interval subculture</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>In vitro</strong></td>
<td>½ Ms supply, Manito 2-4%, 3%</td>
<td>15-18°C</td>
<td>3 months</td>
<td>Shoot, cluster</td>
</tr>
<tr>
<td>maintenance</td>
<td>Sucrose 2mg/l BAP</td>
<td>1000 lux</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60% humidity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplication</td>
<td>Ms Supplement 2mg/l BAP</td>
<td>25-28°C</td>
<td>4 weeks</td>
<td>Shoot</td>
</tr>
<tr>
<td></td>
<td>1500 lux</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution</td>
<td>½ Ms suppl 2mg/l AAA Active Carbon without sucrose</td>
<td>2500 lux diffuse light</td>
<td>4 weeks</td>
<td>Rooted plantlets</td>
</tr>
</tbody>
</table>

**Table 4.** Distribution of banana plantlets.

<table>
<thead>
<tr>
<th>Agencies involved</th>
<th>No. of accessions</th>
<th>Scope of work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phu Ho Fruit Research Center</td>
<td>12</td>
<td>Evaluation and addition to the field collection</td>
</tr>
<tr>
<td>Institute of Biotechnology</td>
<td>15</td>
<td>Molecular research work, Virus indexing, Biodiversity</td>
</tr>
<tr>
<td>Fruit and Vegetable Institute</td>
<td>11</td>
<td>IMTP-fusarium</td>
</tr>
<tr>
<td>Applied Science and Technology Center of Nghe An province</td>
<td>4</td>
<td>Micropropagation</td>
</tr>
<tr>
<td>Agricultural Cooperative</td>
<td>5</td>
<td>Field trial</td>
</tr>
<tr>
<td>Haiduong province</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural Cooperative Hatay province</td>
<td>10</td>
<td>IMTP, field trial</td>
</tr>
</tbody>
</table>

**Pests and diseases of banana**

In a survey conducted by D.V. Thanh in the north and by Nuong in south Vietnam in 2000, a total of 19 pathogenic micro-organisms, 4 nematode species and several insects were observed on bananas grown in the field (Table 5).
Table 5. Level of damage caused by pests and diseases in different genotypes.

<table>
<thead>
<tr>
<th>Pests and diseases</th>
<th>Significant level</th>
<th>Attacked genome groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusarium wilt (Fusarium oxysporum)</td>
<td>+++</td>
<td>ABB, BB</td>
</tr>
<tr>
<td>Black sigatoka (Mycosphaerella fijiensis)</td>
<td>++</td>
<td>AAA, AA, AAB</td>
</tr>
<tr>
<td>Leaf speckle (M. musae)</td>
<td>++</td>
<td>AAA</td>
</tr>
<tr>
<td>Yellow sigatoka (M. musicola)</td>
<td>++</td>
<td>AAA, AA</td>
</tr>
<tr>
<td>Cordana leaf spot (Cordana musae)</td>
<td>+</td>
<td>ABB, BB</td>
</tr>
<tr>
<td>Freckle (Guignardia musae)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Anthracnose (Colletotrichum musae)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Verticillium sp.</td>
<td>+</td>
<td>ABB</td>
</tr>
<tr>
<td>Erwinia sp.</td>
<td>+</td>
<td>ABB, BB</td>
</tr>
<tr>
<td>Pseudomonas sp.</td>
<td>+</td>
<td>AAA, AA</td>
</tr>
<tr>
<td>Cladosporium musae</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Chloridium spp.</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Banana bunchy top virus (BBTV)</td>
<td>++</td>
<td>AAA, AA</td>
</tr>
<tr>
<td>Banana bract mosaic virus (BBMV)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Cucumber mosaic virus (CMV)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Banana streak virus (BSV)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Nematodes</td>
<td>Root-knot nematode (Radopholus similis)</td>
<td>+</td>
</tr>
<tr>
<td>Meloidogyne sp.</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Pratylenchus coffeae</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Insect pests</td>
<td>Corm borer (Cosmopolites sordidus)</td>
<td>++</td>
</tr>
<tr>
<td>Banana aphid (Pentalonia nigronervosa)</td>
<td>++</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Mealy bug (Planococcus sp)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
<tr>
<td>Leaf roller (Erionata thrax)</td>
<td>+</td>
<td>All genotypes</td>
</tr>
</tbody>
</table>

The most important and popular banana cultivars in Vietnam belonging to genome group AAA/AA such as ‘Chuoi Tieu’, ‘Chuoi Bom’, ‘Chuoi Ngu’, ‘Chuoi Cau’ and ‘Chuoi Com’ are infected by sigatoka diseases and bunchy top virus. The symptoms of BSV are often recorded on ‘Chuoi Cau Lun’ (AAB).

Another important disease is fusarium wilt, which attacks on genome group ABB/BB. Vakili et al. (1968) estimated that 85% of ‘Chuoi Xiem’ in orchards are infected with fusarium wilt. Presently, Foc also caused damage in ‘Chuoi Cha Bot’ (AB/ABB). Major insect pests recorded to infect banana such as corm borer are considered to be very destructive. Banana aphids play an important role in spreading viral diseases.

In 1997, Thanh et al. recorded that 28 nematode species are parasitic on banana with four important species: Helicotylenchus sp., Pratylenchus coffeae, Meloidogyne incognita and Radopholus similis.

**Indexing and detection of disease**

To produce a healthy seedling, different diagnostic techniques were developed.

B.T.N Lan and L.T. Hong (2002) conducted some experiments for comparison of different buffers of ELISA in detecting BBTV. The result showed that Tris D-S-BSA gave the highest OD (Table 6 and Figure 3).
At SOFRI, BT Lan and LTT Hong obtained good results in using TC. PCR technique was used for identifying banana streak virus on bananas grown in different provinces in the south of Vietnam. Five specific primer pairs of five BSV strains were used. The BSV strain found in Vietnam belongs to Mysore strain (Table 7).

Table 6. Effect of different buffers on ELISA in BBTV detection (2002).

<table>
<thead>
<tr>
<th>Banana sample</th>
<th>Tris-D</th>
<th>TrisD-S</th>
<th>TrisD-S BSA</th>
<th>TrisD-SM</th>
<th>PBS-TNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control buffer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- (a)</td>
</tr>
<tr>
<td>Healthy plant (bc)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>- (a)</td>
</tr>
<tr>
<td>Disease leaf (b)</td>
<td>0.71</td>
<td>1.49</td>
<td>1.54</td>
<td>1.03</td>
<td>0.65</td>
</tr>
<tr>
<td>Pseudostem (b)</td>
<td>0.55</td>
<td>0.92</td>
<td>0.9</td>
<td>0.71</td>
<td>0.55</td>
</tr>
<tr>
<td>Disease leaf (c)</td>
<td>0.65</td>
<td>121</td>
<td>1.2</td>
<td>0.93</td>
<td>0.42</td>
</tr>
<tr>
<td>Pseudostem (c)</td>
<td>0.52</td>
<td>0.8</td>
<td>0.73</td>
<td>0.59</td>
<td>0.42</td>
</tr>
</tbody>
</table>

Note:  
a, negative by DAS-ELISA  
b, using multiclonal antibodies of Bio-RAD  
c, using monoclonal antibodies supplied by Prof. J. H. Su  
Tris: 0.5M tris buffer PH: 7.5; D: 0.1%, Na-DIECA, S, sucrose: 5%  
BSA: Bovin sera Albunuim; SM, skim milk: 0.5%.

Figure 3. Results of ELISA on BBTV.

BBTV in South Vietnam is genome type II

Table 7. BSV strain identified by IC-PCR in Vietnam.

<table>
<thead>
<tr>
<th>Banana sample/primers</th>
<th>Cavendish</th>
<th>Mysore</th>
<th>Gold finger</th>
<th>Obino l’ewdi</th>
<th>Imove</th>
<th>Vietnam</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH/c12</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MysF/MysR</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>OLF/OLR</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GF-F/GF-R</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IM-F/Im-R</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cav-f/Cav-R</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
A quick disease-indexing method has been developed at SOFRI and VASI to help farmers easily select a healthy planting material. In the south, a quick technique of disease detection had been tested and transferred to the growers so that farmers can select good, healthy motherplants or suckers. This is through the changing color of stained banana sucker slices (Figure 4).

Due to the assistance of FFTC, TBRI and Prof Hong-Ji Su, VASI had applied a successful and quick detection technique of BBTV and BMV in identifying clean planting materials grown in nurseries and field. Infected plants are recognized if the strip has two color bands.
Use of tissue culture to produce healthy planting materials

The use of tissue culture in banana production has been recommended and carried out by many research institutes all over the country such as VASI, SOFRI and the Agriculture Genetic Institute of Tropical Biology since more than a decade ago. In 2002, the Ministry of Agriculture and Rural Development issued the 10 TTC 530-2002 protocol or the standard of banana TC seedling on Cavendish CV, middle Cavendish.

The micro-propagation system for producing clean banana planting materials consists of major steps: selecting plants, \textit{in vitro} propagation, virus indexing, establishment of nursery and transplanting in the field (Figure 5).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{micro-propagation-system.png}
\caption{Micro-propagation system.}
\end{figure}
Extension activities

The banana micro-propagation system consists of many stages and this system is established as a service to the laboratory and research stations of different provinces and growers. The procedure of transferred technology is thus differentiated in three levels depending on the infrastructure facilities and knowledge capability. In the case of tissue culture, the province’s laboratory extension activities include organizing training courses for techno-transfer in tissue culture and field planting techniques.

In some farm stations where there is only one greenhouse or nursery, trainings on hardening rooted plantlets, establishing plantlets in the nursery and field transplanting are conducted.

Farmers are provided the planting materials in pots and are required to properly manage the plantlets in the field.

In the last 5 years (1998-2004), a total of 200 000-900 000 plantlets were provided for field planting and other activities. The major cultivars propagated are ‘Tieu Nho’ (Giant Cavendish), ‘Tieu Lun’ (Dwarf Cavendish) and ‘Chuoi Tay’ (Kluai Namwa). Table 8 shows the number of plantlets produced.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Genotype</th>
<th>Synonym</th>
<th>2001</th>
<th>2002</th>
<th>2003-2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Ngu Tien’</td>
<td>AA</td>
<td>‘Kluai sa’</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>‘Tieu Nho’</td>
<td>AAA</td>
<td>‘Giant Cavendish’</td>
<td>100</td>
<td>100</td>
<td>500</td>
</tr>
<tr>
<td>‘Chuoi Tay’</td>
<td>ABB</td>
<td>‘Kluai namwa’</td>
<td>50</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>‘Tieu Cao Hong’</td>
<td>AAA</td>
<td>‘Lakatan’</td>
<td>50</td>
<td>100</td>
<td>250</td>
</tr>
<tr>
<td>Exotics</td>
<td></td>
<td></td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>210</td>
<td>362</td>
<td>908</td>
</tr>
</tbody>
</table>

Table 8. Number of banana plantlets propagated for farmers, 2001-2003.
Most farmers in the northern provinces, Hanoi, Hatay, Haiduong, Hungyen, use in-vitro plantlets. In-vitro plantlets have vigorous root system and good growth potential so the cycle time is shorter. Fields planted with tissue-culture bananas look healthy, with a uniform in growth and overall yield is 15-20% higher than that of suckers (Figure 6). However, tissue-cultured plantlets showed some somaclonal variation and cost higher than suckers. The variations found are variegation, upright leaves and bunch structure (Table 9).

### Table 9. Comparison of micro-propagated plantlets and suckers.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Plantlets</th>
<th>Suckers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival rate in field</td>
<td>86%</td>
<td>80%</td>
</tr>
<tr>
<td>Uniformity</td>
<td>High</td>
<td>Lower</td>
</tr>
<tr>
<td>Disease infected plant</td>
<td>5-7%</td>
<td>30%</td>
</tr>
<tr>
<td>Yield</td>
<td>28 t/ha</td>
<td>20 t/ha</td>
</tr>
<tr>
<td>Variant</td>
<td>2-3%</td>
<td>None</td>
</tr>
<tr>
<td>Price of planting material</td>
<td>US$0.2/plantlet</td>
<td>US$0.04/sucker</td>
</tr>
</tbody>
</table>

**Figure 6. Banana field experiments on suckers vs. TC plantlets**

**Conclusion**

### Constraints in banana production
- Banana cultivars are infected by many important pests and diseases: fusarium wilt, black sigatoka and BBTV.
- The farmers normally adopt inferior cultivation technologies and conduct improper management
- Lack of market places, hence there are difficulties in selling processed and fresh bananas.

### Future plans
- Evaluation and selection of excellent new varieties from the local and introduced genetic materials.
- Effective use of disease-diagnostic methods in propagation system for producing healthy planting materials.
• Improvement of postharvest technology and techno-transfer to farmers.
• Establishment of new market places to help farmer sell their banana products.

References
Table 10. Banana accessions maintained in national repository in 2004.

<table>
<thead>
<tr>
<th>ITC code</th>
<th>Accession name</th>
<th>Number of plantlets</th>
<th>Growing status</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0312</td>
<td>‘Pisang Jari Buaya’</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>0504</td>
<td>FHIA-01</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>0505</td>
<td>FHIA-02</td>
<td>5</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>0506</td>
<td>FHIA-03</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>0570</td>
<td>‘Williams’</td>
<td>20</td>
<td>very good</td>
<td></td>
</tr>
<tr>
<td>0643</td>
<td>‘Cachaco’ (Bluggoe)</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>0712</td>
<td>AA cv Rose</td>
<td>20</td>
<td>very good</td>
<td></td>
</tr>
<tr>
<td>1122</td>
<td>‘Gros Michel’</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1123</td>
<td>‘Yangambi Km5’</td>
<td>10</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1264</td>
<td>FHIA-17</td>
<td>20</td>
<td>very good</td>
<td></td>
</tr>
<tr>
<td>1265</td>
<td>FHIA-23</td>
<td>10</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1282</td>
<td>GCTCV-119</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1283</td>
<td>SH3436-9</td>
<td>--</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>1296</td>
<td>TMBx1378</td>
<td>15</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1297</td>
<td>TMBx5295</td>
<td>--</td>
<td>--</td>
<td>+</td>
</tr>
<tr>
<td>1307</td>
<td>SH-3640</td>
<td>10</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1319</td>
<td>FHIA-18</td>
<td>20</td>
<td>good</td>
<td></td>
</tr>
<tr>
<td>1332</td>
<td>FHIA-21</td>
<td>20</td>
<td>good</td>
<td></td>
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Status of banana R&D in the Pacific

Mary Taylor*

Importance of bananas

Bananas rank as one of the most widely grown and consumed crops in the Pacific. There is also a significant genetic diversity in the banana gene pool in the Pacific, with Papua New Guinea, Solomon Islands and Vanuatu having the greatest diversity. Most indigenous Pacific bananas are Eumusa section hybrids, some of which are plantains, while others have a thinner, sweeter fruit, which can be eaten raw. Separate from the Eumusa complex are the Fe’i bananas of the Australimusa Section. The Fe’i banana was introduced to the Marquesas and may be a New Guinean or New Caledonian domesticate. The Fe’i bananas are characterized by their erect bunches and purple sap and also have a very orange or yellow/orange-colored edible flesh. For instance, the ‘Karat’ variety of the Fe’i bananas found in Pohnpei in the Federated States of Micronesia has short, plump fruits with orange-yellow flesh. There are different types of ‘Karat’ banana with different sizes and shapes but all high in beta-carotene, the provitamin A carotenoid which is converted into vitamin A in the body. ‘Karat’ bananas have been traditionally used as a weaning food in Pohnpei and other parts of Micronesia.

FAO production data in 2003 state production figures of 80 800 tonnes on 10 100 hectares, suggesting an average production of 8 tonnes per hectare for the Pacific, excluding Papua New Guinea. In Papua New Guinea, 725 000 tonnes were produced on 52 000 hectares, suggesting an average production of 14 tonnes per hectare.

Despite their nutritional importance, bananas are not a priority crop for national agricultural research and extension programmes in most Pacific Island countries, largely because they are not considered an important cash crop. Consequently, government and donor funding for banana research and development is limited.

R&D highlights

The Secretariat of the Pacific Community (SPC)

The SPC Regional Germplasm Centre (RGC) distributes accessions of bananas, taro and sweet potatoes to the 22 SPC member-countries.

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and territories. INIBAP has provided FHIA lines and modest funding for the multiplication and distribution of new banana lines in the region (Table 1).

Table 1. Banana accessions held in SPC RGC, Fiji

<table>
<thead>
<tr>
<th>RGC ACC NO</th>
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<td>A17</td>
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<td>MS07</td>
<td>SH-3640</td>
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FHIA-01, FHIA-02, FHIA-03, FHIA-17, FHIA-18, FHIA-23, and FHIA-25 have been distributed to American Samoa, Cook Islands, Federated States of Micronesia, Fiji, Guam, Marshall Islands, New Caledonia, Palau, Samoa, Solomon Islands, Tonga, and Wallis and Futuna. In 2004, 520 tubes of FHIA bananas have been distributed, containing plantlets and proliferating tissues. In most countries, these have been planted out rather than further multiplied in tissue culture. Evaluation forms have been sent to all countries receiving FHIA lines, and this information will be compiled in a publication.

The SPC is also promoting the Fe’i banana and supporting the work in Pohnpeii of the Department of Agriculture and the Island Food Community of Pohnpeii, a NGO recently established in Pohnpei. Work carried out by Dr Englberger in Pohnpeii has shown that the levels of several key nutrients in the Fe’i banana can significantly contribute to human health. In Micronesia, for example, about half the total energy requirements and more than the required Daily Intake (RDI) of vitamin C are provided by consumption of the local cultivars. Iron levels are between 30-50% of RDI, and reach ca 100% for consumption of cultivars with the highest iron contents reported. Zinc levels are only reported for a few cultivars; these levels correspond to ca 20% of daily requirements. Beta-carotene (provitamin A) contents vary, but for some cultivars levels are sufficient to provide more than the RDI of vitamin A. The natural variation in nutrient levels in bananas is higher than previously suspected, as illustrated by the work of Englberger et al (2003). In a study of banana species indigenous to Pacific islands, levels of beta-carotene, more than twenty times that is found in standard cultivars, were obtained. At Micronesian consumption levels of
Status of banana R&D in the Pacific

bananas, the amounts of beta-carotene found correspond to several times the daily requirement.

In support of the work done in Pohnpei, SPC is responding to the concern of nutritionists in the region about Pacific Islanders’ decreasing intake of local foods, and their increasing reliance on less healthy imported foods. Rice, sugar and wheat flour, as well as fatty meats and refined foods, are rapidly replacing traditional Pacific staples such as taro (*Colocasia*), giant swamp taro (*Cyrtosperma*), yam, banana, breadfruit, pandanus, coconut and seafood in Pacific diets. This change in lifestyle has led to health problems on an epidemic scale, including diabetes, heart disease, vitamin A deficiency and some cancers.

Although the impact *Musa* is having on health is very much confined to Pohnpei, there is a significant interest elsewhere in the Pacific to access the Fe’i bananas from Pohnpei and to evaluate collections in other countries for their carotenoid value. This important genus could contribute more to improving the health of Pacific Islanders. As a result of this Pacific-wide interest and need, SPC is working with the relevant stakeholders in Pohnpei on the Fe’i banana. The objectives of the project are:

(1) To further distribute the Fe’i bananas in Pohnpei and carry out a survey to determine their impact and acceptance.

(2) To establish tissue cultures of Fe’i bananas in SPC RGC, Suva, Fiji.

(3) To develop and distribute documentation promoting Fe’i bananas to the wider Pacific.

The eventual aim is to establish a regional collection of these carotenoid-rich bananas in the RGC. This would be achieved by collecting widely from the Pacific region, and from this total collection, establishing a core collection, which would be conserved in the SPC RGC and be available for distribution and evaluation, after virus indexing.

To date, the SPC RGC has supported the publication of “Pohnpei Bananas: A Photo Collection, Carotenoid-Rich varieties”, and has purchased from the Island Community of Pohnpei, 100 copies for distribution. The booklet covers 31 different Pohnpei cultivars, presented as bunches, hands (groups of individual fruits), fingers (individual fruits), and whole plants, according to provitamin A carotenoid levels of the fruit. The booklet has been funded by several agencies, namely Centre for Disease Control and Prevention, United Nations Children’s Fund, Australian Embassy, Pohnpei State Agriculture, Sight and Life, SPC Pacific Agricultural Plant Genetic Resource Network (PAPGREN) and SPC Lifestyle Health. The booklet
was made available at the recent Ministers of Agriculture and Forestry and Heads of Agriculture and Forestry (HOAFS) held in Suva, Fiji, in September. The President of Fiji opened the meeting and on looking at the booklet, requested his own personal copy.

**America Samoa**

Bananas are considered the most valued local crop along with taro, and until recently the American Samoa School Land Program, funded by the US Federal Government, paid a realistic cost for locally grown banana and taro. This source of funding stopped in January of this year, the reason given was that school children were no longer interested in eating these more traditional foods.

There is no research and development as such, but there have been several workshops aimed at improving banana production in the country. The workshops have focused on forced ripening, black leaf streak disease, plant-parasitic nematodes and organic farming. Publication on banana nematodes and black leaf streak disease are available online (http://www2.ctahr.hawaii.edu/adap2/ascc_landgrant/technical_papers.htm). America Samoa has received the FHIA lines and evaluation is in progress.

**Cook Islands**

Before the 1980s, bananas were an important export commodity for the Cook Islands – fresh fruits were shipped fortnightly to New Zealand. The industry was supported with subsidies by the government. However, in the late eighties export ceased as it was no longer viable. Constraints due to irregular shipping, low yields, high input costs, lack of credit and stringent competition from other countries affected the industry. Currently about 20 acres are under banana cultivation, with the majority being the Cavendish type. About 50% are grown for home consumption, with the remaining 50% being sold on the local market. There is a potential market for sun-dried bananas, as current demand necessitates importing dried bananas from overseas.

There is no significant research and development in bananas in the Cook Islands except for the evaluation of introduced banana varieties, such as the FHIA lines. These are currently being evaluated on-station, but will soon be distributed to selected islands, and interested farmers.

**Fiji**

Fiji has received some of the FHIA lines (FHIA-03, FHIA-17, FHIA-23 and FHIA-25) and is currently evaluating them at the main research
station. SPC RGC has recently provided more plants to the tissue culture laboratory at the research station for multiplication as there are plans to do field trials for these lines in other parts of the country.

**Kiribati**

FHIA lines, Yangambi and SH-3640 were distributed to Kiribati in 2003. They have already been planted in the nursery and some plants have been given to interested farmers on South Tarawa.

**Marshall Islands**

Marshall Islands received *in-vitro* plantlets of FHIA-01, FHIA-02, FHIA-03, FHIA-17, FHIA-18, FHIA-23, FHIA-25, Saba and SH-3640. Some of these were maintained in tissue culture, but losses occurred due to power outage and an associated rise in temperature. The plants that were eventually transferred to the nursery established well in soil, and some of the FHIA lines, namely FHIA-01, FHIA-17 and FHIA-23 are in the fruiting stage. Some plantlets of SH-3640 are in the nursery and are ready to transfer to the soil. Field trials are continuing, and data on plant growth, sucker production and quality performance are being recorded.

Marshall Islands is implementing a project, funded through FAO-TCP, aimed at improving food security and inter-island exchange/trade, through providing assistance to small-scale farmers. The project is providing disease-free planting material and banana agronomy training – new cultivars will be evaluated for their suitability to the Marshall Islands atoll environment. *In vitro* propagation is being used to produce the planting material for this project. The local cultivar, ‘Jilubuki’ (Mysore type), and other introduced cultivars, such as the FHIA lines will be propagated. The project hopes to facilitate income generation for the outer atolls through sales of bananas to the commercial centres of Majuro and Ebeye (Kwajalein).

A farmer training workshop on banana improvement was held in September 2003, jointly organized by the Ministry of Research and Development, FAO and Land Grant. This workshop is part of the FAO-funded food security project, and focused on training farmers in the sustainable management of atoll banana production by the adoption of the narrow-pit system of planting bananas.

**New Caledonia**

Following the BBTV eradication programme which commenced in 2000, the area under banana cultivation has decreased drastically.
Furthermore, New Caledonia was hit by cyclone “Erica” in March 2003, which further decreased production. For 2003 only 320 tonnes of banana (60% dessert and 40% cooking bananas) were officially recorded (compared to 1250 tonnes produced in 2000). The main constraints to banana disease continue to be pests and diseases which include BBTV, *Cosmopolites sordidus*, and black leaf streak (BLS) disease. The BLS disease is prevalent throughout New Caledonia, hence the interest in the FHIA bananas. Currently chemical treatments are used to deal with BLS. FHIA lines (17, 18, 23 and 25) have been received from the SPC RGC and are under evaluation. More data would be available but the plants were all damaged by cyclone “Erica”. Compared with local varieties, these FHIA lines appear to be very susceptible to stress.

The banana collection has 80 different varieties, of which 30 are belonging to the Maia maoli and Popoulou sub-groups. They are specific to the country and are of significant cultural and socio-economic value. These varieties are under threat because of BBTV, and therefore are being established *in vitro* for conservation at CIRAD in Montpellier, France. The morphological characterization of the collection is in progress. MGIS training has been received, but the availability of resources is hindering progress in this area.

There is a need to produce a significant volume of planting material of cooking bananas belonging to the Maia maoli and Popoulou sub-groups to replace all the plants destroyed by BBTV. However, there is concern that if they are multiplied *in vitro*, BSV will be activated. New Caledonia is evaluating a rapid multiplication technique established in Cameroun (CARBAP).

**Pohnpei, Federated States of Micronesia (FSM)**

Banana is one of the most important crops in Pohnpei and throughout FSM. The College of Micronesia – FSM Cooperative Research and Extension Land Grant Programme extension unit – Cooperative Extension Service (CES) has a programme on bananas, which includes training in the villages on cultural practices and management from the preparation of planting materials through to harvesting. Sustainable banana production is being emphasized in both home gardens and the agroforestry system of planting. Pohnpei has received all of the seven FHIA lines from the SPC RGC, and they have been planted at two sites. FHIA-01 and FHIA-03 have consistently showed black leaf spot resistance at both sites. The performance of the other lines appears to be more dependent on conditions, with FHIA-17, FHIA-18 and FHIA-23 showing preference for the drier conditions. Collection of data has been hindered by the cyclones in 2002 and 2003, but it is
expected that data collection will be completed in December 2004.

The Department of Agriculture in Pohnpei has been very active in promoting local bananas. Health research relating to banana has been conducted by nutritionist Dr Lois Englberger in Kosrae, Pohnpei, and Chuuk, three of the four states of the Federated States of Micronesia, and it is largely the result of Dr Englberger’s work that has stimulated the interest in the Fe’i bananas in the Pacific. Local bananas were found to be very high in carotenoid levels. ‘Karat’ was found to contain over 25 times the beta-carotene content of Cavendish, and ‘Utin Iap’ contained 250 times the beta-carotene content of Cavendish. In addition, ‘Karat’ has a relatively high content of calcium, and has been found to have resistance to fungal diseases, including BLS.

A germplasm collection has been established with 32 local varieties and 8 introduced varieties. To promote the local bananas, a booklet, poster and calendar have been produced, and at World Food Day, there were competitions for the “best” carotenoid rich variety and also for recipe development. As a result of the awareness raising carried out by the Department of Agriculture and the Island Food Community of Pohnpei, there has been a significant increase in the number of local market vendors and also in the volume of locally marketed bananas. Dr Englberger presented a paper on her work at the recent international banana meeting and this has raised interest in Pohnpei’s bananas globally. Requests for germplasm have been received from as far as South Africa.

**Solomon Islands**

A collection of 81 bananas has been established in Makira, on the island of Maleita - the result of a partnership between the Solomon Islands Planting Material Network (PMN) and the Manivovo Rural Training Centre. One of the network members attended the MGIS training in Malaysia, and is using a simplified version of the descriptors to characterize the collection. Another member of the network has a smaller collection in the highlands and is planning to use the same descriptors for this collection. The Manivovo collection and the work being done by PMN have inspired members of NGOs from Vanuatu (Farm Support Association) and Bougainville to start their own collections.

There is also interest from the Department of Health in the Solomon Islands to look at the nutritional value of the bananas in the collection, in particular, the carotenoid levels.
Processing of bananas

The questionnaire for information on Musa processing was distributed to several of SPC-member countries. Most countries felt that the questionnaire was not really relevant to their situation, although there is significant interest in banana processing. Questionnaires were returned from Cook Islands and Pohnpei. In the Cook Islands, processing is limited to chips, dried bananas using Cavendish and Lady Finger – with both products regular availability was an issue. The processing “business” is small-scale – there are no private companies specializing in production, or universities/research centres with food science programmes. However, because of the importance of tourism in the Cook Islands, banana products are desirable and currently the government imports products (such as dried bananas) to satisfy the demand. A FAO-TCP project is currently underway to promote the production and processing of local food crops. The project will run for two years, and women from all of the islands will be trained in production and processing by consultants from Thailand.

In Pohnpei, various locally-made products are available, but again, the frequency of availability is limited. These products include chips, traditional baked pudding, and more recently ice-cream. In October of this year, the Island Food Community of Pohnpei invited a food processing consultant for a workshop, focusing on small-scale food processing. Over 100 participants were involved. There was a great deal of interest from the community for new banana-based products, such as chips, banana jam, banana chutney and other products.

Future directions for bananas in the Pacific

Multiplication and distribution of improved banana lines

The SPC RGC will continue to multiply and distribute improved banana lines to the Pacific countries. At present, this includes mostly FHIA lines, but this can be extended to include other lines, should they be relevant for the Pacific.

• SPC will work with member-countries and determine their needs for Musa germplasm.
• SPC is implementing a survey so that the evaluation information on the FHIA lines, which have been distributed can be compiled and made available throughout the region.
**Establishment of a regional collection of Pacific bananas**

The SPC RGC and the Plant Genetic Resources Network (PAPGREN) will continue to work with the Department of Agriculture in Pohnpei and the Island Food Community of Pohnpei in promoting the nutritional benefits of local cultivars of banana, in particular, the Fe’i banana. Funds have been transferred to Pohnpei to facilitate the distribution of suckers of selected cultivars to farmers and the first transfer of Fe’i bananas to the RGC is planned for early 2005. Where possible, support will be provided to other countries where there is interest in local cultivars, and where there is a need to identify and promote those cultivars of nutritional value.

**Reference**


**Acknowledgement**

All the country information has been kindly provided by staff working either for national agricultural research departments or for NGOs.
Recent R&D of banana in Taiwan

Chi-Hon Chen* and Chih-Ping Chao

From 2003 to 2004, the major achievements of research and development of banana in Taiwan include (1) the release of a new fusarium wilt-resistant, high-yielding variety ‘Formosana’ for commercial planting, (2) the establishment of banana corporate farms, (3) the evaluation of Temporary Immersion System for commercial production of plantlets, and (4) the introduction of 19 accessions of Musa germplasm from INIBAP Transit Center (ITC).

Release of a new fusarium-wilt resistant, high-yielding variety ‘Formosana’ for commercial planting

Taiwan banana, mainly ‘Giant Cavendish’ (Cavendish group, AAA), is famous for its excellent eating quality and the market has been oriented for export to Japan for more than one century. However, the banana industry in Taiwan has been severely jeopardized by fusarium wilt, caused by Fusarium oxysporum f.sp. cubense (Foc) race 4, since 1968. The most effective approach to manage fusarium wilt is the use of a resistant cultivar. Several promising cultivars or clones derived from somaclonal variation of ‘Giant Cavendish’ such as Tai-Chiao No.1, Tai-Chiao No.3, GCTCV-105 and GCTCV-217 from 1990 to 1997 were confirmed to have stable resistance to fusarium wilt. However, these resistant clones are inferior to ‘Giant Cavendish’ in yield potential or in fruit quality. In 2002, a somaclonal variant, GCTCV-218, was officially registered as ‘Formosana’, which is characterized by having a high level of wilt resistance and high yield.

The impact of releasing ‘Formosana’ to banana growers for commercial production in Taiwan from 2003 to 2004 were described as follows.

Planting acreage

In 2002, a total of 2.2 M plantlets of this new cultivar were produced for commercial planting, mainly in southern Taiwan. About 0.9 M of ‘Formosana’ plantlets were planted in 2003. The total acreage of ‘Formosana’ plantation reached 1300 ha, accounting for 40% of the total banana growing area. In 2004, the cultivated acreage of ‘Formosana’ remained approximately 1200 ha, of which about 50% plantation was established with suckers, 40% with plantlets, and less than 10% with ratoon crop.

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**Fusarium wilt incidence and VCG analysis**

The fusarium wilt incidence on ‘Formosana’ orchards averaged 6.5% (ranging from 0 to 30%), which is significantly lower than 30.2% (ranging from 5 to 80%) of ‘Giant Cavendish,’ the wilt-susceptible cultivar. The higher rate of disease incidence on some farms was usually associated with poor drainage, sandy and acidic soil or inappropriate application of fertilizer and herbicide.

Four VCG groups, VCG 0120, VCG 0121, VCG 0123, and VCG 01213-01216, have been reported previously in Foc population in Taiwan. Since 2003, all the isolates of Foc collected from different regions in Taiwan, analyzed by pathologist of QDPI, Australia, were identified to be VCG 01213-01216, suggesting the possible change of Foc population in Taiwan.

**Amount of ‘Formosana’ banana exported to Japan**

The harvested bananas of ‘Formosana’ and ‘Giant Cavendish’ were separately packed (12 kg/carton) for export to Japan since February 2003. From February to July 2003, a total of 2.64 M cartons were shipped to Japan, of which 40% were ‘Formosana’ bananas, an increase of 34% (1.97 M cartons) over the amount of banana exported in 2002. Suffering from severe typhoon damage in the autumn of 2003, the amount of Taiwan banana exported to Japan during the same period 2004 was reduced to 1.51 M cartons, of which 35% was ‘Formosana’ bananas.

**Evaluation of fruit quality of ‘Formosana’ in Japanese market**

The overall opinion of Japanese importers and ripening processors about ‘Formosana’ from 2003 to 2004 are as follows:
- The aroma of ‘Formosana’ banana does not reach the standard of ‘Giant Cavendish’ banana.
- After ripening, the deep yellowing in the peel of ‘Formosana’ banana is more appealing to consumers than that of ‘Giant Cavendish’.
- Above all, the loss of ‘Formosana’ banana per carton upon arrival in Japan is lower than 5%, which is much less than 13-15% of ‘Giant Cavendish’.
- More bananas are now sold in supermarkets in Japan. Since the younger generation is the major banana consumer and is basically in favor of fruits with good appearance and fair price, ‘Formosana’ banana is believed to have greater potential.
Establishment of banana corporate farm

Extremely high production cost, severe damage to the fruit skin and uneven fruit quality are the major production constraints for Taiwan banana under the small-producer farming system. These problems render Taiwan banana less competitive in the export market. The key to solving these problems is to increase production unit by introducing a mechanized, corporate farming system.

Acreage of corporate farm

In 2003, a total of 236 ha of corporate farms were established, each farm ranging from 10-40 ha. Each corporate farm was either managed by a single banana grower or invested by a group of farmers. In 2004, the total area of corporate farm expanded to 337 ha, averaging 9-36 ha per corporate farm.

Mechanized cultivation techniques and its efficacy

The machineries used for cultivation in the 20 ha experimental TBRI farm from 2003 to 2004 include bagging machine, bunch transportation tractor and an automatic packing house, which were all introduced from Australia. The tractor equipped with locally-designed mist sprayers is used for controlling foliar disease or weeds, and the one with the cone-shape duster is also used for fertilizer application. To facilitate the operation on corporate farm, the narrow (1.8 m in width) and wide (4.7 m in width) row with triangular planting system is adopted.

Mist sprayer. By using the tractor equipped with either air-blast style mist sprayer or the 4-wheel drive mist sprayer to control foliar diseases or by using a downward comb shape herbicide sprayer attached to the tractor to control weeds, the time needed to complete one cycle of spray was about 20 hours, which was 2 times faster than that required by the traditional manual operation.

Fertilizer duster. The time needed for fertilizer application by the fertilizer-dusting machine over the 20 ha corporate farm was 21 hours, which was 5.3 times faster than that done by manual operation.

Bagging machine. One bagging machine could handle 150 bunches per worker in 7 hours including removal of bell and flower, thinning of fruit hands, and bagging, which increased 7% of bunch bagging than that done by manual operation.

Bunch transportation tractor. Sixty bunches arranged vertically on a bunch transportation tractor could be sent from field to the packing
station in one shuttle, which was 4 times more in terms of loading
capacity compared to that operated by a farmer’s vehicle.

**Automatic assembly shed.** A capacity of 1200-1500 cartons could be
assembled for export by the new automatic assembly shed, an increase
of 25% over that handled by the traditional way.

**Economic efficiency.** Because the application of fertilizer and pesticide
in the corporate farms was done more efficiently by the newly
mechanized devices, banana plants generally grew well. More than
80% of harvested bunch during the export season had better fruit
quality and improved homogeneity. A net profit of US$5003-8235
(NT$170 085-280 000) per hectare was obtained on a corporate banana
farm.

## Evaluation of Temporary Immersion System for
commercial production of plantlets

The Temporary Immersion System (TIS) can effectively shorten the
production cycle of tissue culture plantlets. In semi-solid system, each
culture flask contains three explants in 45 ml culture medium while
the TIS culture vessel holds 25-30 explants needing only 250 ml of
liquid medium is sufficient. TIS can save about 35% of the amount of
culture medium used for the commercial production of plantlets and
at the same time cut down the cost of agar. The space of incubation
room and labor cost can also be reduced. The initial setting up of TIS
system is costly. The training of technicians both in handling the plant
materials and medium preparation is also important. And, the working
environment needs to be under strict control in order to minimize
contamination.

## Musa germplasm collection from ITC

In January 2004, TBRI received a total of 19 accessions of *Musa*
germplasm from INIBAP ITC. They consist of 13 tetraploids (FHIA-
01, FHIA-02, FHIA-03, FHIA-17, FHIA-18, FHIA-21, FHIA-23, FHIA-
25, SH-3436-9, SH-3640, CRBP, TMBx1378, TMBx5295-1), 5 triploids
(Williams, Cachaco, Gros Michel, Yangambi Km 5 and Pisang Ceylan)
and one diploid (Pisang Jari Buaya). Each accession has 12 tubes, 1-2
plantlets per tube, and is now maintained in the growth room under
minimal growth condition, i.e. at a temperature of 16±1°C and low
light intensity of about 1000 lux. All duplicates of 19 accessions kept in
the test tubes showed normal growth. In mid-October, three plantlets
of each accession were transplanted separately into pots in the
repository net house and will be inspected later by personnel from
BAPHIQ (Bureau of Animal and Plant Health Inspection and
Quarantine) before releasing for field trial.
Special presentations
Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* (Foc) has been a serious problem in some localities in south China banana-producing regions since 1996 (Qi 2001). Race 1 of the fusarium wilt was reported earlier (Zeng *et al.* 1996), whereas race 4 (VCG 01213, 01216) was identified only recently. They are fast spreading and very difficult to control.

Although the plant age, weather, general conditions of root system, the physical state of soils, drainage, the nutrient status of the soil, and the amount of inoculum greatly impact the occurrence and course of the wilt disease, the clone grown is recognized the most important factor to decisively influence the course of infection (Stover and Simmonds 1987). In order to search for different sources of resistance, IMTP trials for fusarium wilt supported by INIBAP and Guangdong province were conducted between 2002 and 2004 in Panyu and Dongguan of Guangdong Province. Fifteen introduced clones plus one local cultivar were included in the evaluation in Panyu. Another 28 Cavendish cultivars were evaluated in Dongguan. This paper is a report of the results of this trial.

**Materials and method**

**Testing sites**

The trials were carried out in Panyu and Dongguan, Guangdong Province, which are located in the center of the Pearl River Delta of Guangdong Province. The field plot for this trial was rented from farmers, and has been seriously infested with Foc, with about 50% of banana trees being devastated in the previous crop.

In November 2000, two fusarium wilt samples collected in Panyu and Zhongshan of Guangdong Province were sent to Australia via Mr Bob Williams. On 14 December 2000, Drs Natalie Moore and Desley Tree identified two VCG groups: 01213 and 01216 (‘tropical’ race 4 strains), which were the same as those in Malaysia and Taiwan (Tang and Hwang 1999; Lee *et al.* 2001).
**Planting materials**

Fifteen cultivars from INIBAP Transit Center (ITC) and one local variety, Baxijiao, were used in the Panyu trial. The ITC clones were 0505 (FHIA 02, AAAB), 0506 (FHIA03, AABB), 0570 (Williams, AAA), 0712 (AA cv Rose), 1122 (Gros Michel, AAA), 1123 (Yangambi KM5, AAA, Ibota), 1264 (FHIA-17, AAAA), 1265 (FHIA-23, AAAA), 1282 (GCTCV-119, AAA), 1283 (SH 3436-9, AAAA), 1297 (TMBx 5295-1, AAAB), 1307 (SH-3640), 1319 (FHIA-18), 1332 (FHIA-21, AAAB) and 1344 (CRBP 39, AAAB).

Five tubes each of banana clones were introduced from ITC on 4 September 2001. The buds in two tubes were multiplied in nine subcultures for sufficient plant numbers. After general quarantine procedures in pots and inside netted plastic houses, *in-vito* cultured plantlets were transplanted into plastic bags and used as planting materials after 60 days of hardening.

**Trial design and tree management**

Trees of 30-50 cm tall were planted in the field with a randomized complete block design on 17 August 2002. Six replication trees in each of three blocks were planted. Plant spacing was 2.0 m between trees, 1.5 m between the narrow rows and 2.0 m between wide rows. All management practices were applied uniformly over the whole trial site. Inoculum was increased by adding chopped, infected banana corms and stems from neighbouring orchards to the soil on 30 August 2002. Each plant in the experimental orchard received 1000 g of this inoculum. For other managements, the technical guidelines of Carlier *et al.* (2003) were generally followed, with no application of fungicides in soil or on foliage. Trees were irrigated with river water.

**Data collection**

Generally one investigation each month after December 2002 was carried out on fusarium wilt. One investigation on leaf spot diseases was done 6 months after planting. Due to its very light occurrence throughout the year and no visible difference among cultivars, the leaf spot disease is not analysed in this report. The means of data from each average of plots were listed and compared.

**Investigation on fusarium wilt.** During the growth period, three external symptoms were recorded on fusarium wilt: yellowing of erecting leaf, splitting of pseudostem, and collapse of petiole with leaf lamina in green colour. With a sharp spade, banana trees were examined internally to verify the presence of the disease and internal ratings of
disease severity at harvest, or if plants are going to die before yielding fruit (Carlier et al., 2003). However, due to two successive strong typhoons on 23/24 August and 12/13 September 2003, most of the mother plants fell down and did not reach the stage of harvest.

Investigations on agronomic characteristics. Agronomic characteristics of standing leaf number, height of pseudostem at flowering time, bunch weight, number of hands and fingers, and when applicable, number of functional leaves at harvest were recorded.

Results and discussion
Most trees of ‘AAcv Rose’, ‘Gros Michel’ and ‘Yangambi Km 5’ grew slowly and weakly, indicating that they may not be accustomed to the environmental conditions in the experimental field.

External and internal symptoms of fusarium wilt disease in bananas
There were three types of symptoms in typical banana fusarium wilt disease in different genome groups. They are: upward leaf yellowing in Cavendish type (Figure 1A); leaf petiole collapse in Fenjiao (Pisang Awak) type (Figure 1B); stem cracking in young trees (Figure 1C); and vascular discoloration in stem and corm (Figure 1D). Diseased corms rotted under most conditions.

First external symptom was observed in 210-350 days in planting cycle (Table 1). ‘Gros Michel’ and TMBx 5295-1 were the earliest to show yellow leaves 210 days after planting. Gros Michel was severely stunted, showed internal necrosis, and never reached flowering stage. More or less external symptoms may be seen in other clones (Table 2). ‘Baxijiao’ and ‘Williams’ had the highest ratio of diseased trees, being 72.2% and 44.4% respectively. Their internal discoloration index was 2.8 and 2.5 (Table 2). High ratio of leaf yellowing in FHIA-03, ‘Yangambi Km 5,’ GCTCV-119 and FHIA-18 were recorded, yet their vascular discoloration was not visible. ‘AA cv Rose’ did not show any external symptoms although minimum internal vascular discolouration was observed.

Due to typhoon damage, only a few trees were confirmed to have died of fusarium wilt disease. There were no trees of FHIA-03, ‘Yangambi Km 5’ and GCTCV-119 dead from wilt, which might be confirmed by the discoloration index (Table 2). However, 20% of ‘Baxijiao,’ ‘Williams,’ SH3436-9, FHIA-18 and CRBP39 trees died during the planting cycle. Seventy two percent of ‘Williams’ trees were destroyed by Foc.
Table 1. Days of plant disease resulting from fusarial wilt in the planting cycle in the IMTP3 trial conducted in Panyu, Guangdong Province. Planting date: 17 August 2002.

<table>
<thead>
<tr>
<th>Clone</th>
<th>Days of disease from planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-02</td>
<td>295±91</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>314±62</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>352±47</td>
</tr>
<tr>
<td>AA cv Rose</td>
<td>348</td>
</tr>
<tr>
<td>‘Gros Michel’</td>
<td>210</td>
</tr>
<tr>
<td>‘Yangambi km 5’</td>
<td>348</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>333±60</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>340±33</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>348</td>
</tr>
<tr>
<td>SH3436-9</td>
<td>348</td>
</tr>
<tr>
<td>TMBx5295-1</td>
<td>210</td>
</tr>
<tr>
<td>SH-3640</td>
<td>348±0</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>255±120</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>320±57</td>
</tr>
<tr>
<td>CRBP39</td>
<td>327±52</td>
</tr>
<tr>
<td>‘Baxijiao’</td>
<td>348</td>
</tr>
</tbody>
</table>

Table 2. Occurrence of fusarium wilt determined by external and internal symptoms in the planting cycle in the IMTP III trial conducted in Panyu, Guangdong Province. Planting date: 17 August 2002.

<table>
<thead>
<tr>
<th>Clone</th>
<th>Number of plants evaluated</th>
<th>Plants with external symptoms %</th>
<th>Internal discoloration index</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-02</td>
<td>18</td>
<td>22.2</td>
<td>2.8±1.7</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>18</td>
<td>38.9</td>
<td>1.0</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>18</td>
<td>72.2</td>
<td>2.5±2.1</td>
</tr>
<tr>
<td>cv. Rose</td>
<td>18</td>
<td>0</td>
<td>1.8±1.1</td>
</tr>
<tr>
<td>‘Gros Michel’</td>
<td>18</td>
<td>100.0*</td>
<td>3.7</td>
</tr>
<tr>
<td>‘Yangambi km 5’</td>
<td>12</td>
<td>33.4</td>
<td>1.0</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>18</td>
<td>25.0</td>
<td>4.8</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>18</td>
<td>38.9</td>
<td>1.5</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>18</td>
<td>27.8</td>
<td>1.1±0.2</td>
</tr>
<tr>
<td>SH3436-9</td>
<td>18</td>
<td>5.6</td>
<td>1.6±1.0</td>
</tr>
<tr>
<td>TMBx5295-1</td>
<td>18</td>
<td>38.9</td>
<td>2.0±1.4</td>
</tr>
<tr>
<td>SH 3640</td>
<td>18</td>
<td>11.1</td>
<td>2.7±2.1</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>18</td>
<td>38.9</td>
<td>1.0±0.0</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>18</td>
<td>27.8</td>
<td>2.6±1.4</td>
</tr>
<tr>
<td>CRBP39</td>
<td>24</td>
<td>16.7</td>
<td>2.8±1.1</td>
</tr>
<tr>
<td>‘Baxijiao’</td>
<td>18</td>
<td>44.4</td>
<td>2.8±1.1</td>
</tr>
</tbody>
</table>

*Plants were severely stunted and did not reach flowering stage.
Figure 1. The external and internal symptoms in banana fusarium wilt disease. A. Petiole collapse, usually in Fenjiao; B. Leaf yellowing; C. Stem cracking; D. Browning and necrosis of corms in cross section.

GCTCV-119 seemed resistant to fusarium wilt in the planting cycle in Panyu of Guangdong. This clone came from Taiwan Banana Research Institute, and it was considered of intermediate to high resistance level (Tang and Hwang 1999). In October 2003, 44 suckers of planting cycle were collected and replanted in the neighboring plot for further evaluation of fusarium resistance and agronomic characteristics. External and internal symptoms of fusarium wilt were observed after August of 2004. There were twelve diseased trees as of November 2004. Trees with no wilt symptoms began to flower since mid September, with 11 trees flowered before early November. Average plant height in the second cycle was 2.57 m.

Most of the trees in Dongguan trial plots died of fusarium wilt diseases before shooting or harvesting during the year of 2003. Further evaluation for those cultivars with a few living trees is underway.

In order to screen the true resistant clones, suckers of resistant GCTCV-119 clones in the planting cycle were marked and meristems were cultured in vitro for rejuvenation. Plantlets were planted in farmers’ field in April, June, July and August 2004, to find out best planting season and optimize the field management for growth improvement. Preliminary results showed good tree structure, leaf arrangements and
growth vigour from tissue-cultured trees. The total number of trees is more than 1000, which can be the materials of further selection.

**Agronomic characteristics**

In the planting cycle, complete agronomic data were gained in a few clones. Trees of ‘Gros Michel’ and ‘Yangambi km 5’ did not flower in the first year. No fruit reached mature stage before being infected with disease in ‘Baxijiao,’ ‘Williams,’ FHIA-17, FHIA-18 and FHIA-23 (Table 3). Trees shot between 310 and 400 days after planting in the planting crop cycles (Table 3). FHIA-03 had the shortest growth cycle, shooting 300 days after planting (range 290 and 330 days), and the fruit maturing at 388 days after planting (range 307 to 472 days).

GCTCV-119 started to shoot 397 days (range 389 to 406 days), and fruits mature 510 days after planting. Its yield, bunch and finger shapes were acceptable and eating quality was very good. However, one or two small leaves could be seen in a tree during early spring, indicating its sensitivity to chills. Attempts are being tried to improve its growth through adjustment of planting time and optimization of field management.

**Table 3.** Agronomic characteristics of 12 clones in the planting cycle of the IMTP-3 fusarium trial in Panyu, Guangdong Province, China. Planting date: 17 August 2002.

<table>
<thead>
<tr>
<th>Clone</th>
<th>Days from planting to shooting</th>
<th>Plant crop cycle (days)</th>
<th>Plant height at shooting (cm)</th>
<th>Bunch weight (kg)</th>
<th>No. of hand</th>
<th>Fruit number at harvest</th>
<th>No. functional leaves at flowering</th>
<th>No. functional leaves at harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-02</td>
<td>363.7±21.0</td>
<td>516.0</td>
<td>6.0±1.4</td>
<td>80.0±22.6</td>
<td>13.6±0.7</td>
<td>6.5±0.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-03</td>
<td>314.7±21.5</td>
<td>388.7±22.5</td>
<td>256.5±19.1</td>
<td>11.7±8.7</td>
<td>6.0</td>
<td>88.0±5.6</td>
<td>12.8±0.2</td>
<td>9.3±1.2</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>323.1±8.1</td>
<td></td>
<td></td>
<td></td>
<td>13.9±0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cv. Rose</td>
<td>314.1±29.3</td>
<td>516.0</td>
<td>205.3±13.6</td>
<td>8.7±0.6</td>
<td>116.0±5.6</td>
<td>12.8±1.9</td>
<td>10.6±1.9</td>
<td>5.3±1.1</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>364.0±18.4</td>
<td></td>
<td></td>
<td></td>
<td>14.0±0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-23</td>
<td>394.0</td>
<td></td>
<td></td>
<td></td>
<td>13.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>397.8±12.4</td>
<td>510.0</td>
<td>227.8±5.6</td>
<td>13.9±2.7</td>
<td>6.4±0.5</td>
<td>99.4±11.5</td>
<td>13.5±0.7</td>
<td>6.2±1.6</td>
</tr>
<tr>
<td>SH3436-9</td>
<td>395.3±12.1</td>
<td>501.5±20.5</td>
<td>270.3±11.5</td>
<td>6.1±2.3</td>
<td>8.6±0.9</td>
<td>155.5±3.5</td>
<td>12.3±0.6</td>
<td>2.2±0.2</td>
</tr>
<tr>
<td>TMBS×5295-1</td>
<td>382.5±16.3</td>
<td>516.0</td>
<td>312.5±0.0</td>
<td>-</td>
<td>6.0</td>
<td>70.0</td>
<td>8.4±7.3</td>
<td>4.5</td>
</tr>
<tr>
<td>SH 3640</td>
<td>338.9±11.4</td>
<td>428.7±51.3</td>
<td>250.9</td>
<td>12.3±8.1</td>
<td>8±1.4</td>
<td>112.0±26.9</td>
<td>14.6±1.4</td>
<td>7.0±4.2</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>342±13.8</td>
<td></td>
<td></td>
<td></td>
<td>13.3±0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHIA-21</td>
<td>355.4±19.6</td>
<td>451.5±91.2</td>
<td>281.0</td>
<td>6.5±0.7</td>
<td>71.0±14.1</td>
<td>12.5±0.7</td>
<td>8.0</td>
<td></td>
</tr>
<tr>
<td>CRBP 39</td>
<td>306.6±11.9</td>
<td>501.5±20.5</td>
<td>259.4±68.8</td>
<td>5.8</td>
<td>10.3±2.3</td>
<td>143.5±36.1</td>
<td>11.0</td>
<td>4.9±1.2</td>
</tr>
<tr>
<td>‘Baxijiao’</td>
<td>333.5±3.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.7±0.2</td>
<td></td>
</tr>
</tbody>
</table>
SH3436-9 also had a long growth stage, shooting 395.3 days after planting, whereas CRBP 39, cv Rose and FHIA-03 started to shoot around 300 days after planting, with shorter growth stages.

Crop cycles ranged between 400 and 500 days. FHIA-03 was the shortest (388.7 days). FHIA-02, cv Rose and TMBx5295-1 needed 516 days, while GCTCV-119, SH 3436-9 needed more than 500 days.

Most of the trees had stems of 200 and 300 cm tall, while TMBx 5295-1 was the tallest at 312.5 cm at shooting, and cv Rose was the shortest at 205.3 cm.

Fruits were harvested only in five clones (Table 3). The biggest bunch was collected in GCTCV-119, with 13.9 kg. No fruit could be harvested in other trees because of poor growth or disease or typhoon damages.

Hand numbers were between 6 and 8 and total fingers 36 and 155. SH 3436-9 had 155.5 while CRBP 39 had only 36.1 fingers. Fingers of SH 3436-9 were small and underdeveloped. Leaf numbers ranged between 10 and 14 at shooting stage and 4 to 9 at harvest. However, SH 3436-9 had only 2.1 leaves at harvest.

One hundred seventy out of 288 trees survived in the second cycle, which did not mean that they were all resistant to fusarium wilt disease since suckers of some susceptible clones may live for two or more years. More observation has been done in the second cycle (Table 4). ‘Gros Michel,’ Yangambi km 5, FHIA-23 and SH-3640 still did not shoot, and no mature fruit bunch was harvested in FHIA-17, GCTCV-119 and SH3436-9.

Three ‘Williams’ ratoon trees were alive and its fruits fully developed. Yet its short stems (1.86 m vs normal 2.0m~4.0m, Daniells 1995), as recorded in earlier report (Orjeda et al. 1999), were obviously somaclonal off-types from long-term conservation. ‘Williams’ is the reference cultivar for FOC susceptibility. Due to many subcultures and long-term conservation, somaclonal variation may be possible. Suckers were collected and in vitro cultured for further evaluation.

Fingers of FHIA-02 were short and thick and with soft flesh. Fruit bunch of FHIA-03 was big and compact. Although its fruit bunch mature early and eating quality was good, cv Rose trees were short and slender, with loose hands and less superior appearances.

Fifteen trees of GCTCV-119 survived in the second cycle, and five trees flowered in the first and second plots. Its leaf sheaths were arranged compactly and closely, which may be the main reason for ‘Choke throat’ when bunch emerged.
The tree stature of ‘Gros Michel’ was tall and erect. Even though they seemed healthy, they did not flower in the second cycle. A few trees of SH3436-9 flowered and set upward bunches with small fingers. Three trees of ‘Baxijiao’ flowered in the ratoon crop. However, all leaves turned yellow and wilted before fruit matured. Therefore fingers were not fully mature when harvested. Normally, the bunch weight of ‘Baxijiao’ is over 20 kg. It seemed that suckers of ‘Baxijiao’ might live for one to two years.

Conclusion

Before the trial, pathogen samples taken from the vascular bundles of diseased plants were sent to Australia for identification. VCG 01213 and 01216 were found in these samples, which belong to the tropical race 4 (N. Moore, personal communication). Therefore, the trial should be interpreted as the reaction of banana clones to race 4 of fusarium wilt.

According to the number of trees that survived 12 months after planting, in combined with external symptoms and vascular discolouring, the tested cultivars can be classified as:

Susceptible: ‘Williams,’ FHIA-17, ‘Gros Michel,’ ‘Baxijiao.’ Less than 8 trees survived, over 40 % with external symptoms, or discolouration index over 3.0. All the cultivars tested in Dongguan were susceptible ones.

Table 4. Agronomic characteristics of 12 clones in the 2nd crop of the IMTP-3 fusarium trial in Panyu, Guangdong Province, China.

<table>
<thead>
<tr>
<th>Clone</th>
<th>No. of trees</th>
<th>Flowering to harvest (days)</th>
<th>Plant height (cm)</th>
<th>Girth (cm)</th>
<th>Bunch weight (kg)</th>
<th>No. of fingers</th>
<th>No. of leaves, flowering</th>
<th>No. of leaves, at harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-02</td>
<td>7</td>
<td>93.5</td>
<td>277.7</td>
<td>52.3</td>
<td>15.3</td>
<td>7.8</td>
<td>109.4</td>
<td>11.9</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>8</td>
<td>86.0</td>
<td>288.0</td>
<td>61.4</td>
<td>12.1</td>
<td>6.4</td>
<td>87.4</td>
<td>10.3</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>3</td>
<td>105.7</td>
<td>186.3</td>
<td>48.3</td>
<td>13.6</td>
<td>8.3</td>
<td>130.0</td>
<td>12.3</td>
</tr>
<tr>
<td>cv. Rose</td>
<td>9</td>
<td>84.0</td>
<td>180.1</td>
<td>25.4</td>
<td>6.4</td>
<td>8.2</td>
<td>60.1</td>
<td>8.8</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>1</td>
<td>296.0</td>
<td>67.0</td>
<td>9</td>
<td>135.0</td>
<td>8.8</td>
<td>8.8</td>
<td>6.0</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>15</td>
<td>256.5</td>
<td>51.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SH 3436-9</td>
<td>1</td>
<td>283.0</td>
<td>65.0</td>
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<tr>
<td>TM lays 5295-1</td>
<td>8</td>
<td>80.5</td>
<td>307.6</td>
<td>46.9</td>
<td>6.1</td>
<td>74.7</td>
<td>11.3</td>
<td>6.0</td>
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<tr>
<td>FHIA-18</td>
<td>6</td>
<td>81.0</td>
<td>263.7</td>
<td>54.9</td>
<td>10.6</td>
<td>7.7</td>
<td>155.5</td>
<td>11.3</td>
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<tr>
<td>FHIA-21</td>
<td>10</td>
<td>73.0</td>
<td>306.2</td>
<td>45.5</td>
<td>9.6</td>
<td>6.3</td>
<td>76.1</td>
<td>11.2</td>
</tr>
<tr>
<td>CRBP 39</td>
<td>7</td>
<td>80.0</td>
<td>251.4</td>
<td>48.4</td>
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<td>10.9</td>
<td>7.3</td>
<td>115.5</td>
<td>12.0</td>
</tr>
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</table>
Screening of banana clones for resistance to fusarium wilt in China

Intermediate: CRBP-39, TMBx5295-1, FHIA-17, FHIA-18, SH-3640, SH3436-9. Eight to twelve trees survived, 25 to 40% with external symptoms, or vascular discoloration index 1.5 to 3.0.

Resistant: FHIA-02, FHIA-03, cv Rose, FHIA-23, GCTCV-119, FHIA-21. More than twelve trees survived, 25% with external symptoms, or discoloration index below 1.5.

In other regions, bunch weight of GCTCV-119, the Cavendish clone developed by Taiwan Banana Research Institute (TBRI) through selection from somaclonal variants, ranged from 3.3 and 22.2 kg, average crop cycle was 533 days, with hand number of 6.67 and plant height of 2.51 m (Orjeda et al. 1999). Although in some sites it did not show good resistance to fusarium wilt like in Taiwan (Orjeda et al. 1999), it performed well in Panyu, probably attributing to the similar genetic background of the pathogen. Its fruit quality was very good and yield was acceptable. However, one shortcoming was its long cropping time. Strong suckers or tissue-cultured plantlets are encouraged as planting materials, and planted in deep, fertile soils. Extra nitrogen and potassium fertilizers may be needed, in order to stimulate tree growth. GCTCV-119 was sensitive to low temperatures in winter and early spring. A few short and narrow leaves were seen in spring. 'Choke throat' was seen in a few trees. Change of planting time would be effective in order for trees to grow in warm season. Production of virus-free plantlets, screening of new good strains or improvement through induction are also attempted.

‘Williams’ has been a cultivar being easily subjected to somaclonal variation, especially those buds under long-term storages (Orjeda et al. 1999). Therefore, variation with resistance or tolerance to Foc race 4 may be expected. In vitro culture has been established for further observation.

Some of the improved FHIA hybrids showed high level of resistance. However, the texture and flavor of the fruit are not acceptable to the consumers in China who are accustomed to the flavor of Cavendish, ‘Xiangjiao’ or ‘Fenjiao.’

References
Montpellier, France.


Population structure of wild bananas, *Musa balbisiana*, in China determined by SSR fingerprinting and cpDNA PCR-RFLP

X. J. Ge*, M.H. Liu, W. K. Wang, B. A. Schaal and T. Y. Chiang

Abstract

Both demographic history and dispersal mechanisms influence the apportionment of genetic diversity among plant populations across geographical regions. In this study, phylogeography and population structure of wild banana *Musa balbisiana*, one of the progenitors of cultivated bananas and plantains, in China were investigated by an analysis of genetic diversity of SSR fingerprint markers and cpDNA PCR-RFLP. A chloroplast DNA genealogy of 21 haplotypes identified two major clades, which correspond to two geographical regions separated by the Beijiang and Xijiang Rivers, suggesting a history of vicariance. Significant genetic differentiation was detected among populations with cpDNA markers, a result consistent with limited seed dispersal in wild banana mediated by foraging of rodents. Nuclear SSR data also reveals significant geographical structuring in banana populations. In western China, however, there was no detected phylogeographical pattern, possibly due to frequent pollen flow via fruit bats. In contrast, populations east from the Beijiang River and the population of Hainan Island, where long-range soaring pollinators are absent, are genetically distinct. Colonization-extinction processes may have influenced the evolution of *Musa* populations, which have a metapopulation structure and are connected by migrating individuals. Effective gene flow via pollen, estimated from the nuclear SSR data, is 3.65 times greater than gene flow via seed, estimated from cpDNA data. Chloroplast and nuclear DNAs provide different insights into phylogeographical patterns of wild banana populations and, taken together, can inform conservation practices.

Keywords: cpDNA PCR-RFLP, fruit bat, long distance colonization, metapopulation, *Musa balbisiana*, phylogeography, SSR fingerprinting, vicariance, wild banana

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Establishment of embryogenic cell suspension culture and plant regeneration of banana (*Musa* spp.) for gene transformation

Xue-Lin Huang,* Yue-Rong Wei, Xia Huang, Jia Li, Wang Xiao and Xiao-Ju Li

Abstract
A protocol was developed for the establishment of pre-transformation plant regeneration system and gene transformation of the popular local cultivars of banana (*Musa* AAA cv. Williams, *Musa* AA cv. Mas) and plantain (*Musa* AAB Silk cv. Guoshanxiang; *Musa* ABB cv. Dongguandajiao).

The floral explants of *Musa* AA cv. Mas that produced the highest frequency of embryogenic calli were the floral hands of the 6th to 12th rows. Nine µmol/L 2, 4-D was the most effective for -callus induction, causing 41.0% of the male floral hands to form callus and 7.5% of the induced calli to become embryogenic callus. The embryogenesis efficiency of the calli was $280 \times 10^3$ embryos per ml PCV, and 14.2% of the mature embryos could be converted into plantlets. Cauliflower-like compact buds (multiple buds) could be induced from a single adventitious bud meristem of *Musa* AAB Silk cv. Guoshanxiang in P4 medium, and 97.6% of the calli induction percentage could be reached on callus induction medium. 17.4% of embryogenic callus was produced from the induced calli. After culture on mature medium for 60 days, 14.5% of the somatic embryos induced from embryogenic callus could be germinated, and 11.1% of the germinated embryos were converted to plantlets. Five types of calli were induced from micro-cross section of plantain (*Musa* ABB cv. Dongguandajiao) through improving B5 medium. The results of histology and physiological characters of these calli showed that type V could be considered as the embryogenic callus and somatic embryogenesis could be induced from the V type callus. The somatic embryos however could not be successfully converted into plantlets. The suitable conditions for the cultures need to be further studied.

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* Professor and Chairman Department of Biology, School of Life Sciences, Zhongshan (Sun Yat-Sen) University, Guangzhou, China.
Compared with LBA4404, EHA105 was the more efficient strain for the transformation of the banana cultivars. Kan and Hp were suitable selective agents for selection of putative transformed cultures, however the explant was very sensitive to baster. The transient expression rate of GUS gene was increased 5 folds if the explants were pretreated with 0.2mol•L⁻¹ mannitol. At least five transgenic plants of *Musa* AAA, cv. Brazil and seven of the plantain (*Musa* ABB, cv. Pisang Awak) were obtained. A vector, pCAMBIA2301 containing the *hpt* gene controlled by the Ubil promoter, was used to successfully transform the suspension cell of *Musa* cv. Mas (AA). The cells formed somatic embryos on the induction medium containing 50mg/L geneticin as selective agent. GUS expression could be detected afterwards in the transformed embryos which could be germinated after culture for one month on the germination medium.

**Introduction**

Production of banana and plantain in China ranks 5th on the world. The problems of banana production in China are the same as in other countries. Biotechnology and gene technology, together with conventional methods, can assist in overcoming the problems of banana production in developing new banana cultivars, and establishment of a suitable plant regeneration system *in vitro* is required for biotechnology and gene technology.

Although several important progress in pre-transformation plant regeneration system has been made, the application of embryogenic cell suspension for genetic improvement of *Musa* is limited because of the low induction percentage of embryogenic callus, low conversion frequencies of plant regeneration from the somatic embryos and long culture times, i.e. 10 to 18 months depending on cultivar have been documented from culture initiation to plant regeneration. Therefore, an optimal protocol for embryogenic cell suspensions from different cultivars needed to be developed.

The main objective of this study is to develop an optimal protocol for the establishment of a pre-transformation plant regeneration system and gene transformation of popular local cultivars of banana and plantain in China.

**Materials and methods**

*Establishment of plant regeneration system for transformation*

The cultivars used in this study were: *Musa* AAB Silk cv.
Establishment of embryogenic cell suspension culture


To establish the embryogenic cell suspensions, young floral hands of immature male flower of cv. Mas (AA) and *Musa paradisiaca* Linn (ABB) were used as the initial explants for callus induction. The medium for callus induction of Mas(AA) consisted of MS (Murashige and Skoog 1962) salts and vitamins supplemented with different concentrations of 2,4-D, 4.1µmol/L biotin, 5.7µmol/L IAA, 5.4µmol/L NAA, 87 mmol/L sucrose, and solidified with 7 g/L agarose. The medium for callus induction of *Musa paradisiaca* Linn cv. (ABB) contained MS basic salts with 1mg/L biotin, 1mg/L IAA, 1mg/L NAA, 4 mg/L 2,4-D, 30 g/L sucrose and solidified with 7g/L agar.

The scalps of *Musa* AAB Silk cv. Guoshanxiang and the micro-cross section of *Musa* ABB cv. Dongguandajiao were used as initial explants for the callus induction. During callus induction from scalps, P4 medium was used as induction medium which consisted of MS salts and vitamins supplemented with 100 µmol/L BAP and 1µmol/L IAA. During callus induction from the micro-cross section, the method described by Okole and Schulz (1996) was used.

Embryogenic callus were selected from the induction calli according to histological observation and their morphology. Suspension culture was done in various media dependent on the cultivars and explants. Medium ML was used for the suspension culture of the embryogenic callus from young floral hands of Mas (AA) cultivar and scalps of AAB Silk cv. Guoshanxiang. The ML contained MS basic salts with 4 µmol/L biotin, 680 µmol/L glutamine, 100 mg/L malt extract, 130 mmol/L sucrose and 9.0 µmol/L 2,4-D.

For the histological study, the samples were fixed in 2% glutaraldehyde and the methods described by Li and Gu (1982) were followed.

**Agrobacterium-mediated transformation**

Micro- cross section was used as explants to investigate the factors affecting the early phase of the transformation. This was done by detecting the transient expression of GUS gene either controlled by CaMV35S or rice actin1 promoter in expression vectors constructed from pBA002 according the method described by Huang *et al.* (2002). The embryogenic cell suspensions was derived from young floral hands of immature male flower of cv. Mas (AA) (Wei *et al.* 2005) to study the effects of selective agents on the differentiation of the embryogenic cells. Three expression vectors, pCAMBIA2301 containing
nptII gene, pUB containing hp gene and pBAUbi containing bargene were constructed, respectively (Huang et al., 2002) for the transformation study.

Results and discussion

Somatic embryogenesis from young floral hands of immature male flower of Mas (AA)

The explants that produced the highest frequency of embryogenic calli were the floral hands of 6th to 12th rows. Nine µmol/L 2, 4-D was the most effective on the callus induction. It caused 41.0% of the male floral hands to form callus and 7.5% of the induced calli to become embryogenic callus (Figure 1). Meristematic globules and yellowish, friable embryogenic cultures were obtained after culture for 5-6 months on callus induction medium (Figure 1 B). The suspension cultures were initiated by using the embryogenic calli in liquid medium supplemented with 4.5µmol/L 2, 4-D. Homogeneous, yellowish embryogenic cell suspensions (ECS) were established after 3 months of culture (Figure C, D and E). Somatic embryogenesis with the frequency of approximately $280 \times 10^3$ somatic embryos/mL PCV ECS could be induced from 6 months old ECS on MSD semi-solid media. MSD contained SH (Schenk and Hildebrandt 1972) macronutrients, micro-nutrients, Fe-EDTA and MS vitamins supplemented with 4.5µmol/L biotin, 680µmol/L glutamine, 2mmol/L proline, 100 mg/L malt extract, 1.1µmol/L NAA, 0.2µmol/L zeatin, 0.5µmol/L kinetin, 0.7µmol/L $N^6$-(2-isopenteny1) adenine, 29mmol/L lactose, 130mmol/L sucrose and solidified with 2g/L gelrite, pH5.8. After a 3-month culture, 17.3% of somatic embryos germinated on germination media (MG). It consisted of MS salt, Morel and Wetmore vitamins, 0.2µmol/L 6-BA, 1.1µmol/L IAA, 87µmol/L sucrose. It was also solidified with 2 g/L gelrite, and 14.2% of somatic embryos which could develop into normal plantlets on rooting media if it contains the same composition as that of MG but without auxin and cytokinin.

Histological analysis indicated that after 5 days of the embryogenic induction, bi-cellular and multi-cellular proembryos were observed at the same histological section. Irregular protoderm was differentiated in multi-cellular proembryo after the culture for 15 days. For another 5 days of the culture, the embryos at early globular stage were developed from the proembryos and became either oblong, pear-shaped or scutiform. Mature embryo was formed after culture for 3 months. Epidermis, shoot apex meristem, root apex meristem, and central vascular zone could be distinguished from histological section of the
embryo. The mature embryo could germinate 10 days after being transferred into germination media. Thirty days later, healthy plantlets were converted from the germinated embryos.

Figure 1. Somatic embryogenesis and plant regeneration from immature male flowers of *Musa* AA Pisang Mas cv. Mas.

(A) (Wei et al. 2005) The 12th floral hand as explant for callus induction. Bar=150 mm. (B) Embryogenic mixture of meristematic globules (a) and friable embryogenic callus (b) after 90 days induction. Bar=300 mm. (C) Embryogenic callus with whitish proembryos obtained after 60 days subculture of yellow friable callus. Bar=300 mm. (D) Earlier embryogenic cell suspension composed of single cells, cell aggregates, proembryos and some yellow nodule callus. (E) Ideal embryogenic cell suspension after 3 months subculture. (F) Homogeneous cell aggregates in ideal embryogenic cell suspension. Bar=60 µm. (G) Somatic embryos after planting on somatic embryo induction medium (MSD) for 15 days, Bar=1 cm. (H) Translucent globular and oblong embryos on MSD medium after 40 days of culture. Bar=6 mm. (I) Mature somatic embryos on MSD medium after 90 days of culture. Bar=6 mm. (J) Germinating embryos
Somatic embryogenesis from scalps of Musa AAB silk cv. Guoshanxiang

Cauliflower-like compact buds (multiple buds) could be induced from a single meristem of adventitious bud induced from Musa AAB Silk cv. Guoshanxiang in P4 medium consisted of MS salts and vitamins supplemented with 100µmol/L BAP and 1µmol/L IAA (Wei et al. 2004). However, the time for the multiple buds induction was dependent on the cultivar. For example, Guoshanxiang needed subculture for 5 cycles (35 days for each cycle), and Baxi needed 8 cycles. The investigation of conditions for callus induction from scalps derived from Guoshanxiang multiple buds indicated that 97.6% of the calli induction percentage could be reached on a medium supplemented with 5µmol/L 2,4-D and 1µmol/L Zeatin in the dark, and when multiple buds were pre-cultured in the light with a 16-h photoperiod provided by cool white fluorescent tubes with a light intensity of 30 µmol·m⁻²·s⁻¹(Figure 2).

17.4% of embryogenic callus was produced from the induced calli. After 20 days of culture, yellowish nodular calluses (also called meristematic globules) were observed on the surface of scalps. Embryogenic complexes consisting of whitish or buff and friable embryogenic callus and young somatic embryos appeared on the surface of meristematic globules in 90-120 days of culture. After culture on mature medium for 60 days, 14.5% of the somatic embryos induced from embryogenic callus could be germinated. 11.1% of the germinated embryos were converted to plantlets.

Callus induction and somatic embryogenesis form Musa ABB cv. Dongguandajiao (plantain).

Five types of calli were induced from micro-cross section of plantain (Musa ABB cv. Dongguandajiao) in improving B₅ medium, including B₅ with dicamba (B₅D) and B₅ with 2,4-D (B₅2,4-D), respectively. Both type I and II calli were white, loose and wetish except for type I which was less translucent. Type III was pale yellow, compact and with less water content and small grains. Type IV was milk white, viscous and compact with bigger grains. Type V was pale yellow with compact grains and less water content (Figure 3).
Figure 2. Culture of highly proliferating multiple buds and somatic embryogenesis in *Musa* AAB Silk cv. Guoshanxiang (Wei 2004). (A) Adventitious mud after 3 subcultures from suck bud; (B) Segment of single adventitious bud about 1cm; (C) Cultures of the first subculture 30 days after inoculation in P4 medium; (D) Cultures after 5 subcultures for 105 days; (E) Highly proliferating multiple buds after 5 subcultures for 175 days in the light, S represent scalp with the size of about 3mm×3mm×1.5mm, separated from multiple buds; (F) Highly proliferating multiple buds after 5 subcultures —for 150 days in the dark; (G) Yellow meristematic globules appeared on the surface of scalp on the induction medium after 30 days; (H) Yellow meristematic globules appeared on the single shoot meristem on the induction medium after 90 days; (I) Calluses from the yellow meristem globules of the 7th figure, with the surface becoming friable; (J) Whitish and friable embryogenic callus (arrow), with whitish translucent somatic embryos, on the surface of yellow meristematic globules after 90 days induction; (K) Embryogenic callus inducted directly from scalps and not through meristematic globules stage; (L) Whitish, compact non-embryogenic callus from scalps; (M) Somatic embryos were inducted on MSD, arrow represented germinated somatic embryo with green sheath. Bar=5mm; (N) Mature somatic embryos (arrow) obtained on the surface of embryogenic callus after 150 days induction. Bar=5mm; (O) Germinating embryos with green sheath. Bar=15mm; (P) Regenerated plantlets.
The morphology of callus could be changed by pre-culture and addition of different plant growth regulators (Figure 3). Pre-culture medium was MSDB, including MS basal medium, 2,4-D (18µmol/L) and 6-BAP (18µmol/L). In case of no pre-culture, type I could be induced in B5, while type II and III could be induced in B5, 2,4-D. On the condition of pre-culture, type IV and V were respectively induced by dicamba and 2,4-D. The results of histology and physiological characters of these types of calli showed that type V could be considered as the embryogenic callus and the optimal medium for inducing type V was B5 salts with improving B5 vitamins/ amino acid, sucrose (30g/L), active carbon (1g/L), IAA (1µmol/L) and 2,4-D (27µmol/L). Furthermore, pre-culture of the explants on MSDB was very important to the induction of type V. Somatic embryogenesis could be induced from the type V callus (Li zhe 2004), but the somatic embryos could not be successfully converted into plantlets. The suitable culture conditions for the cultures need to be further studied.

**Figure 3.** The morphology of calli induced from the micro-cross sections of *Musa* ABB cv. Dongguandajiao. (A) type I callus induced by dicamba (bar=150 µm); (B) calli induced by 2,4-D, type III callus is in center and type II callus is around (bar=150 µm); (C) after pre-culture, type IV callus induced by dicamba (bar=200 µm); (D) after pre-culture, type V callus induced by 2,4-D (bar=150 µm) (Li, 2004).

**Agrobacterium-mediated transformation**

Compared with LBA4404, EHA105 was the more efficient strain for the transformation. Kan and Hp was suitable selective agents for banana explant, however the explant was very sensitive to baster because it died after one day of co-culture with baster (0.2mg/L). The transient
expression rate of GUS gene was increased 5 folds if the explant was pretreated with 0.2mol•L-1 mannitol and the Agrobacterium inoculation was disposed by negative pressure produced by vacuum pump. At least five transgenic plants of Musa AAA, cv. Brazil) and seven of the plantain (Musa ABB, cv. Pisang Awak) were obtained. PCR, PCR-Southern blot and Southern blot analysis have confirmed that foreign gene had already integrated into the genome of banana (Huang et al 2000). During the transformation with the embryogenic suspension cells from young floral hands of immature male flower of cv. Mas (AA), pCAMBIA2301 containing hpt gene under control by Ubil promoter, was shown to successfully transform into the suspension cell and the cells formed somatic embryos on the induction medium containing 50mg/L geneticin as selective agent for selection of the putative transformed embryos. GUS expression could be detected in the transformed embryos (Figure 4) which could be germinated after culture for one month on the germination medium. The selection of putative transgenic plants is being undertaken.

Figure 4. Agrobacterium-mediated transformation of the embryogenic suspension cells derived from young floral hands of immature male flower of cv. Mas (AA). (A) cell suspension co-cultured with Agrobacterium for 3 days no GUS expression was detected; (B) cell suspension co-cultured with Agrobacterium for 7 days, GUS expression could be detected; (C) the transformed cells were dead; (D) the transformed cells were alive; (E) Somatic embryo from the transformed cells can be germinated and with strong GUS expression (Blue, G) compared with no transformed embryo (F).
References


Preliminary evaluation of IMTP-III varieties and local cultivars against fusarium wilt disease in South China

Huang Bingzhi, Xu Linbing and Agustin B. Molina, Jr.

Fusarium wilt caused by Fusarium oxysporum f. sp. cubense (Foc) is an important disease in the banana-producing areas of South China. Although Foc race 1 is believed to have been in China earlier, it was only officially reported in 1996 (Qi 2001). This race has been seriously attacking the popular local variety ‘Fenjiao’ (ABB, Pisang Awak).

Fusarium wilt infection on ‘Cavendish’ was reported in localized areas in Panyu District in the late 1990s. Believed to be Foc race 4, this pathogen is regarded as economically important because of its damage to ‘Cavendish’. Recently, some infections were observed on Cavendish farms in Qiongshan and Sanya, Hainan Province (Linbing 2003). Heavy infections were similarly observed in Zhongshan City, Panyu District, Dongguang City, along the Delta Pearl River.

The increasing epidemic of fusarium wilt on Cavendish plantations poses a real threat to the 90% predominantly Cavendish banana industry in South China. In an effort to develop an effective IPM strategy against this disease, a collaborative study between the Guangdong Academy of Agricultural Sciences (GDAAS) and the International Network for the Improvement of Bananas and Plantain (INIBAP) was initiated in 2003. Improved varieties being evaluated through the International Musa Testing Programme (IMTP), which were reported to include fusarium-resistant varieties (Molina et al. 2002) were introduced through the Pomology department of GDAAS and evaluated in the field for their resistance to fusarium wilt.

Materials and methods

Twenty-three IMTP varieties were received as proliferating cultures from INIBAP Transit Centre (ITC) by the Pomology department. These were then immediately multiplied into rooted plantlets. Representatives of each variety were planted and maintained as foundation stocks in an insect-proof nursery at the Pomology department. Tissue-culture seedlings from each variety were used to carry out field evaluation against fusarium wilt.

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Field screening was carried out in two sites, namely Zengcheng and Panyu District, both in Guangzhou, Guangdong Province. Zengcheng was chosen as Site 1. It was previously planted with ‘Fenjiao’, a variety heavily infected by fusarium wilt. Although there were no analyses to determine what VCG type of Foc was present in this site, it was designated as Foc race 1 site, judging from the variety that was severely affected.

Panyu District was selected as Site 2. This area was previously planted with ‘Xiangjiao’ (Cavendish), of which 95% were affected by fusarium wilt. Similarly, no analyses were conducted to determine the actual VCG group of the Foc pathogen found in this area. However, since the previous crop that was heavily infected by fusarium wilt was a ‘Cavendish’ variety, this site was designated as Foc race 4 area.

The planting started on 18 August 2003 in Site 1 and 26 August 2003 in Site 2. Due to the differences in the number of seedlings developed from the original culture, the number of plants per variety was not the same. The number of seedlings ranged from 5 to 20 plants per variety. These were planted in a completely randomized block design.

Disease assessment was done by counting the incidence of infected plants. The infected plants were identified by the typical yellowing and eventual necroses of leaves on unshot plants, which started from the older leaves. The infection was confirmed by examining the internal vascular necrosis. Visual symptoms also included pseudostem splitting.

The plants that survived the attack of fusarium wilt reached maturity, yielded fruits and were evaluated for their agronomic characteristics.

**Results and discussion**

The results of the evaluation in two sites are summarized in Table 1. The measure of resistance and susceptibility of the various varieties were determined by the percentage of infected plants per variety in the two trial sites. Results showed that selection pressure was amply high as reflected by the high percentage of infection in susceptible variety.

In Zengcheng (Site 1) and designated as Foc 1 trial site, ‘Gros Michel’, which is known to be susceptible to Foc 1, and Bita-2 sustained 100 percent infection, while CRBP-39 and ‘Pisang Ceylan’ showed 40% and 10% infected plants respectively. All the other varieties were not affected by fusarium wilt.

Two significant results are evident in Site 2. First, several varieties including the popular ‘Cavendish’ varieties, ‘Baxi’ and ‘Williams’ were
highly susceptible to fusarium wilt in Panyu district, trial Site 2. Although no analysis was done to establish the VCG type in Site 2, the results indicate that Foc race 4 is now a serious disease in South China. Several FHIA varieties, FHIA-17, FHIA-23, SH 34369 and SH-3640, were also observed as susceptible as the ‘Cavendish’ varieties. Two ‘Cavendish’ somaclones from the Taiwan Banana Research Institute (TBRI), which were previously reported resistant to Foc race 4 in Taiwan (Hwang 2000) were observed susceptible in Site 2. The second interesting result is the observation that several varieties, FHIA-01, FHIA-02, FHIA-03, FHIA-18 and FHIA-25 were resistant to the disease in Site 2. GCTCV-119, a ‘Cavendish’ somaclone from Taiwan was relatively resistant to fusarium wilt in Site 2.

Table 2 summarizes some agronomic characteristics of some varieties that were resistant to Foc race 4 in Site 2.

This preliminary study showed very relevant and interesting results. A more extensive and thorough evaluation is planned to be established.

Table 1. Reactions of IMTP varieties against fusarium wilt in two locations.

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<tr>
<th>Varieties</th>
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<th>Site 2**</th>
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</tr>
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<tr>
<td>‘Gros Michel’</td>
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</tr>
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<tr>
<td>‘Baxi’ (control)</td>
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</table>

*Site 1 is considered Foc race 1 trial
**Site 2 is considered Foc race 4 site
This will include a higher number of experimental plants per variety and sequential assessment will be done to determine onset and disease progress rate. Efforts will also be done to characterize the pathogen in the experimental sites. This preliminary study, however, has opened up an important area of banana research concern in China.

References


(a) a susceptible variety showing external symptom of yellowing that starts on older leaves; (b) Huang Bingzhi and Xu Linbing at the Fusarium Experimental Site 2, Panyu District, Guangdong Province; (c) FHIA-02 showing high resistance to Foc race 4 in Site 2 and a severely wilted susceptible variety; (d) a susceptible variety showing internal symptom of vascular necroses; (e) pseudostem splitting observed on a susceptible variety.
Status of banana R&D in Hainan, China

Chen Yeyuan*, Wei Shouxing and Zhang Lei

Hainan is located between 3°20’ and 20°18’ N latitude and 107°50’ and 119°10’ E longitude. With a total land area of 3.5 sq km, Hainan is the smallest province in China. It is however the third producer of banana in China with a planting area of 30 800 ha and total production of 84.19 million tonnes in 2003. In recent years, the yield and planting area are increasing rapidly. However problems on pests and diseases, fertilization and genetic resources management seriously affect the development of banana industry in Hainan. To overcome these constraints, various efforts are in progress at the Chinese Academy of Tropical Agricultural Science (CATAS).

Genetic resource management

In 2003, the Academy, represented by Dr Chen Quibo, signed a Letter of Agreement (LOA) with the International Network for the Improvement of Banana and Plantain (INIBAP), represented by Dr Agustin Molina. Sixty-two banana cultivars were introduced from Belgium, Ecuador, Venezuela, Brazil, Honduras and Taiwan through INIBAP Transit Centre (ITC). The quality and quantity of the introduced material however varies. There are suckers and *in-vitro* cultured plantlets, and some are duplications. The different treatments were thus given to the different situations.

Multi-propagating

Forty-two out of the 62 banana cultivars were taken as ex-plant to be multi-propagated. Fifty seedlings of each cultivar are expected to be received for planting in multi-locations in Hainan in 2005.

*Vice Director, Germplasm Research Institute of Tropical Crops, Chinese Academy of Tropical Agricultural Sciences, Danzhou City, Hainan, China.
Field trial

Forty cultivars were selected (including 23 type germplasms introduced from INIBAP) to be planted in the screen house. But only 36 germplasms survived, including the 21 kinds coming from INIBAP. These are now growing well in the banana nursery of the Tropical Crops Genetic Resources Institute of Chinese Tropical Agricultural Science Academy. After 2 months of observation, FHIA-03, Gros-Michel and TMBx5295-1 have shown the highest stem and big and long leaves (see Table 1).

Table 1. Growth characteristics of the introduced banana cultivars (unit:cm).

<table>
<thead>
<tr>
<th>Accession Name</th>
<th>Height of pseudostem</th>
<th>Leaf length</th>
<th>Leaf breadth</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Pisang Jari Buaya'</td>
<td>57</td>
<td>65</td>
<td>32</td>
</tr>
<tr>
<td>FHIA-01</td>
<td>46</td>
<td>54</td>
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</tr>
<tr>
<td>FHIA-02</td>
<td>55</td>
<td>57</td>
<td>25.5</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>82</td>
<td>86</td>
<td>43</td>
</tr>
<tr>
<td>'Williams'</td>
<td>74</td>
<td>82</td>
<td>37</td>
</tr>
<tr>
<td>'Cachaco'</td>
<td>44</td>
<td>59</td>
<td>29</td>
</tr>
<tr>
<td>AAov Rose</td>
<td>82</td>
<td>82</td>
<td>32</td>
</tr>
<tr>
<td>'Gros Michel'</td>
<td>83</td>
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<td>40</td>
</tr>
<tr>
<td>'Yangambi km 5'</td>
<td>58</td>
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<td>24</td>
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<tr>
<td>FHIA-17</td>
<td>70</td>
<td>74</td>
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<tr>
<td>FHIA-23</td>
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</tr>
<tr>
<td>GCTCV-119</td>
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<tr>
<td>TMBx1378</td>
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<td>TMBx5295-1</td>
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<td>84</td>
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<tr>
<td>SH-3640</td>
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<td>66</td>
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<tr>
<td>FHIA 21(#68)</td>
<td>64</td>
<td>71</td>
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<tr>
<td>CRBP 39</td>
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<td>FHIA 25</td>
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<tr>
<td>GCTCV-106</td>
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<td>65</td>
<td>31.5</td>
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<tr>
<td>GCTCV-247</td>
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<td>76</td>
<td>35.5</td>
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<tr>
<td>'Pisang Ceylan'</td>
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<tr>
<td>Ho-1</td>
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<td>Ho-2</td>
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<td>Ho-5</td>
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<td>Ho-9</td>
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<td>Ho-10</td>
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<td>Ho-11</td>
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</tr>
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<td>28</td>
<td>43</td>
<td>21.5</td>
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<td>TBRI-119</td>
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<td>TBRI-247</td>
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<tr>
<td>FHIA-18</td>
<td>68</td>
<td>74</td>
<td>36</td>
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</tbody>
</table>
Distribution of banana-producing area in Hainan

To accelerate the development of the banana industry, the Academy, on the request of Hainan provincial government, has been carrying out a program on rationalizing the distribution of banana-producing areas in Hainan. The banana-producing areas in Hainan has been divided into four regions, according to the different climate conditions such as typhoon, light, heat, rainfall and the ecological conditions in the island. The target by year 2010 is to increase the area and production to 67 000 ha (Figure 2) and 2 525 900 tonnes respectively.

Southwest region

The region includes Sanya City, Ledong County, Dongfang County, Baoting County and Changjiang County. This region is the traditional and main production area in Hainan. Due to the limitation of land, the region has little potential in increasing production areas for future development. The policy of development suggested for the region is to introduce excellent varieties, in order to increase yield and develop new market.

Northwest region

This region includes Haikou City, Danzhou City, Lingao County, Chengmai County and Dingan County. It is a new area for banana production, with abundant land resource and appropriate climate, hardly harmed by typhoon. The proposal to the region is to increase the planting area.

Mountain region

Danzhou City, Chengmai County, Tunchang County, Qiongzhong County, Wuzhishan, Baisha County are included in this region. This region is in the centre of Hainan Island. The ecological environment is very good, the soil is fertile and there is little pollution. It is suitable for the production of organic banana.

East region

The region includes Haikou City, Wenchang County, Dingan County, Qionghai County, Wanning County and Lingshui County. Banana can be produced all year round but the area is highly prone to damage by typhoon. It is recommended to plant windbreaks around the banana plantation or to plant banana in the area that can avoid the damage of typhoon.
Figure 2. Planned distribution of banana-producing areas in 2010.
Study on the pests and diseases of banana

Major pests and diseases

There was a large scale investigation about pests and diseases in Hainan, Guangdong, Guangxi, Yunnan and Fujian provinces of China from July to September 2004. The results show that the major diseases are yellow sigatoka, banana freckle disease, banana bunchy top, mosaic disease and Panama wilt. The main pests are banana root borer, banana corm borer, banana stem weevil borer, black banana aphid, Spodoptera litura (Fabricius), Thrips hawaiiensis and Tetranychus piercei. In recent years, the damage of Panama wilt is serious in Guangdong and Hainan.

Banana fusarium wilt [Fusarium oxysporum f.sp. cubense (E.F.Smith) Snyder et Hansen] is recorded in Hainan for the first time. On the base of the modified Komada medium, 18 isolates of fusarium wilt of banana from Hainan banana-growing areas were identified by artificial inoculation in glasshouse. The results showed that all isolates in Hainan belongs to 2 physiologic races of race 1 from Fenjiao (ABB Group) and race 4 from Xiangjiao (AAA Group) based on the culturing characters and pathogenic differentiation.

Primary study on pathogenicity and RAPD analysis of pathogens of banana wilt

Identification of physiological race, testing of pathogenicity, RAPD analysis was primarily studied using 18 isolates of Fusarium oxysporum f.sp. cubense from Hainan and Guangdong province. The results showed that 12 isolates from Fenjiao (ABB Group) were race 1, while 6 isolates from Xiangjiao (AAA Group) were race 4. The disease incidence rate of Fenjiao inoculated by race 1 isolates and of Xiangjiao inoculated by race 4 isolates were all 100%; the pathogenicity of the No. 13 isolate from Lizhigou, Shanya, Hainan was the strongest, compared with the other 5 isolates of race 4; RAPD analysis could detect race 1 and 4, geographic origin of isolates, and pathogenicity; primer OPM-15 could be used to identity race 1 and 4.

Study on Tetranychus piercei McGregor

The influences of six different constant temperatures and nine host plants on development and reproduction of Tetranychus piercei McGregor were investigated under laboratory conditions. It could be concluded that temperatures from 28-32°C are the best suitable temperature conditions for the development, survival and reproduction of the mite. Papaya was the more favoured host plant compared with
cherimoya, and banana, and ‘Baxijiao’ (AAA Group) and ‘Gongjiao’ (AA) were the most suitable and unsuitable banana varieties respectively for the development and reproduction of the mite.

The control test of *Tetranychus piercei* has also been carried out. In indoor trail, the pesticides of 40% phoxim, 15% pyridaben, 12.5% guohaimai, 2.5% and 1.8% abamectin were tested. The results showed that the toxicities of 5 insecticides to the mites was arranged in increasing order as abamectin, abamectin+cypermethrin, pyridaben, guohaimai, phoxim. The LC$_{50}$ of the tested insecticides were 0.0586, 0.4415, 34.6817, 35.0268 and 96.1017 ug/ml respectively.

**Table 2. Results of toxicity of the 5 pesticides to female adult of *Tetranychus piercei*.**

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>Virulence equation</th>
<th>Relative coefficient (r)</th>
<th>$\chi^2$</th>
<th>LC$_{50}$ (ug/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phoxim</td>
<td>Y=4.7425x-4.4031</td>
<td>0.9516</td>
<td>0.0733</td>
<td>96.1017</td>
</tr>
<tr>
<td>Pyridaben</td>
<td>Y=4.1991x-1.4671</td>
<td>0.9657</td>
<td>0.0320</td>
<td>34.6817</td>
</tr>
<tr>
<td>Guohaimai</td>
<td>Y=3.1396x+0.1513</td>
<td>0.9241</td>
<td>0.0982</td>
<td>35.0268</td>
</tr>
<tr>
<td>Asabamectin+Cypermethrin</td>
<td>Y=6.6729x+7.3696</td>
<td>0.9939</td>
<td>0.0063</td>
<td>0.4415</td>
</tr>
<tr>
<td>Abamectin</td>
<td>Y=2.4819x+8.0578</td>
<td>0.9756</td>
<td>0.1440</td>
<td>0.0586</td>
</tr>
</tbody>
</table>

In field trials in Hainan Island, the insecticides of pyridaben, asabamectin+cypermethrin sumiekang, phoxim and abamectin were evaluated for control of *Tetranychus piercei* on bananas. Concentration setting was as follows: *Pyridaben* 30 ug/ml, 20 ug/ml, 15 ug/ml; *Asabamectin+cypermethrin* 50 ug/ml, 25 ug/ml, 16.67 ug/ml; *Sumiekang* 133.33 ug/ml, 100 ug/ml, 80 ug/ml; *Abamectin* 4.5 ug/ml, 3.6 ug/ml, 3.0 ug/ml; *Phoxim* 133.33 ug/ml.

The results showed that all the pesticides are good for the control *Tetranychus piercei*, the control effects 1 day after treatment were all above 80% except 40% Sumiekang 80 ug/ml (76.03%), 40% Sumiekang 133.33 ug/ml is the greatest (91.93%). The control effect of *Abamectin* 4.5 ug/ml, 3.6 ug/ml, 3.0 ug/ml and *pyridaben* 30 ug/ml, 20 ug/ml, 15 ug/ml were all increased 7 days after the treatment, in which the effect of *Abamectin* was above 95% and the effect of *pyridaben* was in the range 86~89%; the effect of *asabamectin+cypermethrin*, Sumiekang and *phoxim* declined obviously 7 days later. This indicates that *Abamectin and pyridaben* are the most efficient pesticide. The efficient concentration was 3.0 ug/ml and 15 ug/ml.
**Biological characteristics of Stethorus (Allosstethorus) parapauperculus**

*Stethorus (Allosstethorus) parapauperculus* is a very important predator of *Tetranychus piercei*. The influence of temperature on the development, survivorship and propagation of *S. (Allosstethorus) parapauperculus* have been studied.

**The development of S. (Allosstethorus) parapauperculus**

The relationships between temperature and developmental rates of various stages and a generation could be described by logistic equation model. It showed that the developmental threshold temperature and effective accumulated temperature of a generation were 11.92 and 227.67 day-degrees. It can be estimated that *S. (Allosstethorus) parapauperculus* could finish 18-19 generation yearly in Hainan.

**The survival rate of S. (Allosstethorus) parapauperculus**

It could be estimated that the highest survival rates of existence of egg, the first larva, the second larva, the third larva, the forth larva, pupae and a generation are respectively 94.66%, 93.77%, 96.89%, 96.43%, 99.32%, 94.43% and 74.33%, and the most suitable temperatures are 27.16°C, 26.93°C, 29.47°C, 27.92°C, 26.72°C, 25.25°C, and 27.01°C respectively.

**The fecundity of S. (Allosstethorus) parapauperculus**

At 16°C, the reproductive duration is the longest and at 32°C it became the shortest. The highest average fecundity (595.49 eggs/female) was recorded at 28°C and the lowest (125.05 eggs/female) at 16°C. The mean number of eggs laid daily per female was highest (6.96 egg/female) at 32°C and the lowest (1.08 eggs/female) at 16°C. The life span of female adult had a negative linear relation with temperature. The relationship between temperature and fecundity were fitted by curve regression equations.

Under conditions of changing temperatures, the ladybug can prey on 7150 of eggs or 1157 adults in all of its life. Results show that the *Stethorus (Allosstethorus) parapauperculus* has a strong ability to control *Tetranychus piercei*. Field trials are developed.

**Study on the fertilization techniques of banana**

For the accurate fertilization of banana, the total amount of each kind of essential chemical element required for high yield (75,000 kg/ha) must be analyzed; and the utilization rate of the main chemical fertilizer in the different type of soil must be identified.
The nutrient researches have been developed from planting to harvest time. The researches conclude:

1. Dry heavy ratio of root cap, pseudostem, leaf, fruit, sucker in the period of harvest.
2. The needed amount and proportion of every kind of nutrient in different parts of banana (root, pseudostem, fruit, leaf, sucker).
3. The amount of each kind of element that is demanded in different growth period of banana.
4. The variational regulation of every kind of nutrient in pseudostem and leaf in different periods.
5. Utilization rate of fertilizer in the brick red soil.
6. The N, P and K fertilizer go together with the ratio under the basaltic soil.
7. The distribution of banana roots in soil.
8. Study on the nutritional characteristic of soil on the rhizosphere.

The results suggested that abundant and secondary elements are different in the organ and a single plant. Figure 3 shows that the amount of N element in the fruit and leaf is bigger than in the other organs of banana. The amount of K element is higher in the fruit and the pseudostem than in the other organs. The highest amount of Ca in the banana is found in the leaf. The content of Mg is relatively high in the fruit, leaf and the pseudostem. The five kinds of chemical element are mainly distributed in the fruit, leaf and the pseudostem, but little in the peduncle and root of banana. The amount of the five kinds of element that accumulated in the organs of banana is shown in Figure 4. N is abundant in the fruit, leaf and pseudostem, the amount of K is high in the fruit and pseudostem and Ca in the leaf and the pseudostem.
Figure 3. N, P, K, Ca, Mg comparison in each organ of banana.

Figure 4. N, P, K, Ca, Mg accumulation in each organ of banana.
INIBAP/IPGRI programmes
INIBAP programme on conservation and use of banana diversity

Agustin B. Molina, Jr.*, Jean-Vincent Escalant and Inge Van den Bergh

Bananas and plantain are very important fruit crops in the tropical world. They are grown largely by smallholders and play a major role in food security and income generation for millions of the region’s rural poor worldwide. In terms of gross value of production, bananas are the developing world’s fourth most important food crop after rice, wheat and maize, and as a fruit, they rank first. More than 100 million tonnes of bananas are produced every year in 120 countries in over ten million hectares. Only about 13% of the world’s banana production is exported and 87% is consumed where they are produced, indicating that bananas play a vital role as source of food and income in developing countries. Bananas constitute a major staple food for millions of people and provide a valued source of income through local and international trade.

Production statistics in 2004 show that banana is an important crop in the three major regions, Asia, Latin America and Africa. Most of the export bananas produced comes from Latin America. In contrast, bananas produced in Africa are consumed locally underscoring the importance of banana as a major component of Africans’ daily diet. Table 1 presents the world’s leading banana-producing countries. India topped the list with 16.55 t/ha whereas the Philippines, with a total production of 5.41 t/ha, came in 6th after Uganda, Brazil, Ecuador and China. Except for the Philippines and the three Latin American countries, most of the leading banana-producing countries grow bananas for local consumption.

INIBAP Programme

The International Network for the Improvement of Banana and Plantain (INIBAP), a network of the International Plant Genetic Resources Institute (IPGRI), was established in 1985. It has coordinated the global research effort on banana and promoted the collaboration among countries in banana-related research activities. One of the important project areas of INIBAP is Musa genetic conservation, management and improvement. INIBAP hosts the largest assemblage of Musa

*INIBAP Regional Coordinator for Asia and the Pacific, Los Banos, Laguna, Philippines.
collections through its INIBAP Transit Center located in Catholic University in Leuven, Belgium. INIBAP has also supported the collection, conservation and characterization of *Musa* germplasms in several countries where there is high *Musa* diversity.

**Musa** collection and conservation

**India**

In collaboration with the Indian Council for Agricultural Research (ICAR), INIBAP supported the efforts of the National Research Centre for Bananas (NRCB) in carrying out collection missions in various parts of north-eastern India, western and eastern ghats of India, and Andaman and Nicobar islands. From these explorations, NRCB has assembled 953 accessions including popular cultivar cultigens and wild species both from primary and secondary sources of origin of diversity. These *Musa* germplasm collections were successfully established in the field banks of NRCB, characterized and evaluated for some agronomic traits. Some were deposited at the National Bureau of Plant Genetic Resources (NBPRG) for proper duplication and conservation. Moreover, NRCB participates in the *Musa* Germplasm Information System, a global database management system developed and coordinated by INIBAP. NRCB submits germplasm characterization data to INIBAP for data integration into the MGIS. Subsequently they were given access to the global information available at the MGIS database. The richness of the Indian collection is reinforced by another INIBAP-ICAR

<table>
<thead>
<tr>
<th>Top 10 producing countries</th>
<th>Production (million t)</th>
<th>% of total world production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bananas</td>
<td>Plantains</td>
</tr>
<tr>
<td>India</td>
<td>16.82</td>
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</tr>
<tr>
<td>Uganda</td>
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</tr>
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<td>0.00</td>
</tr>
<tr>
<td>Ecuador</td>
<td>5.90</td>
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<tr>
<td>Rest of the World</td>
<td>21.38</td>
<td>14.21</td>
</tr>
</tbody>
</table>

**Table 1. World’s leading banana-producing countries**

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</tr>
<tr>
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<td>21.38</td>
<td>14.21</td>
</tr>
</tbody>
</table>
collaboration of germplasm exchange where ICAR, through NBPRG and NRCB, received virus-free *Musa* accessions from INIBAP’s International Transit Centre in Leuven, Belgium. These are distributed to various institutions for research purposes.

**Philippines**

INIBAP had supported the efforts to conserve the *Musa* collections in the Philippines. Originally established in 1978 with the support of the International Board of Plant Genetic Resources (IBPGR), which later became IPGRI, the banana germplasm collection at the BPI-DNCRDC in Bago-Oshiro, Davao City was designated as the Southeast Asian Banana and Plantain Resource Center. The genebank holds the Philippines, Malaysia, Thailand, Indonesia and Papua New Guinea collections.

The maintenance of the field genebank encountered difficulties because of infections of viral diseases primarily banana bunchy top virus, banana bract mosaic virus, banana leaf streak virus, fusarium wilt and bacterial wilt. Through the assistance of INIBAP, the *Musa* field collections were rehabilitated in 2002. A total of 205 accessions consisting of 88 accessions from the Philippines, 45 from PNG, 17 from Thailand, 6 from Indonesia, 22 from Malaysia, 32 ITC accessions and 4 reference materials were planted. With the minimal maintenance given to the plants, occurrence of diseases is still an ongoing problem. From 2002 to present, recorded incidences of BBTV is at 5.09%, BBrMV at 9.94% and BSV at 1.39%. For the soil borne pathogens, Moko incidence is 0.46% and Panama Disease at 1.27%.

The BPI *Musa* genebank actively participated in the MGIS programme. The *Musa* collections were morphologically characterized and data were integrated in the global MGIS database.

Through a project funded by the Philippine Council of Agricultural Research, the Institute of Plant Breeding, University of the Philippines at Los Baños carried out a *Musa* collection missions in different parts of the Philippines such as Palawan, Mindoro and Mt. Pinatubo in 1991. Collected materials were planted at the banana field collection at UPLB. Results showed that there are many distinct focus of wild *Musa balbisiana*, contrary to the general belief that *M. balbisiana* is highly uniform. On the other hand, 12 out of the cultivars that were collected in Mt. Pinatubo turned out to be synonyms of known varieties.

**Indonesia**

A Banana Germplasm Conservation and Improvement Cooperation
was innovated between the Indonesian government and INIBAP. This programme was intended to tie up the ongoing banana germplasm conservation project of Indonesia covering the major islands of Sumatra, Java, Sulawesi, Kalimantan with an INIBAP-initiated activity that will finance exploration missions to Maluku and Irian Jaya. Supplemental INIBAP funding also includes training opportunities in germplasm documentation and characterization.

The first banana prospection mission to Maluku covered the islands of Ambon and Ceram. The banana explorers from the Indonesian Fruit research Institute (IFRI) at Solok collected 28 wild species and cultivars. These accessions have been introduced to the national field collection in Solok where banana germplasm earlier gathered from Sumatra, Java and other regions of Indonesia are being assembled. Additional collecting trips are scheduled for Maluku and Irian Jaya. A duplicate Indonesian banana germplasm was maintained in trust for the world community at ITC.

**Vietnam**

In collaboration with Phu Ho Fruit Research Center (PHFRC), a complete national field collection of indigenous germplasm was established in Vinh Phu province, northwest of Hanoi with duplicates of southern banana cultivars planted in Long Dinh Fruit Research Center, Tien Giang province, south of Saigon. This project has collected 107 accessions (19 wild species and 88 cultivars) from Phu Ho and 45 accessions from Long Dinh. The accessions are being conserved and characterized at the PHFRC using banana descriptors from INIBAP. Both field collections are well maintained with local funding support. Some 55 distinct accessions were duplicated *in vitro* at the Vietnam Agricultural Science Institute and shipped to INIBAP's Transit Centre in Belgium.

**China**

Collection missions were conducted in the southern provinces of China bordering Vietnam, Laos and Burma such as Guangxi, Yunnan and Guangdong provinces from 1996-1997. From there, some 53 wild and cultivated banana species were collected and then maintained, characterized and identified for synonyms at the field genebanks in South China Agricultural University (SCAU). Twenty-three accessions were characterized completely using the INIBAP Passport data and submitted to the MGIS.
**Musa improvement and use**

Banana breeding is a difficult and long-term programme. The generally seedless nature and longer gestation of bananas make breeding difficult and expensive. Hence, although bananas are very important fruit crop in many tropical countries, there are just a few serious breeding programmes in the world. Pests and diseases are recognized as the global common denominators as far as major production constraints are concerned. The epidemic of fusarium wilt in Central America in the 50s, and the global outbreak of the virulent black sigatoka had provided impetus to breeding programmes worldwide. In the last 15 years, *Musa* breeding programmes within the INIBAP network have made significant accomplishments, resulting to a number of new, high-yielding and disease-resistant varieties of bananas and plantains. These varieties include both dessert and cooking types, a number of which are considered to hold good potential in Asia. These varieties are evaluated through the International *Musa* Testing Programme (IMTP). IMTP is the evaluation of elite *Musa* breeding lines from various breeding programmes together with some popular local cultivars in different agro-ecological zones worldwide.

The different research institutions in BAPNET-member countries collaborated with INIBAP to embark on a project on the introduction and evaluation of a selection of improved varieties bred by breeding programmes in other countries. Twenty-one varieties were introduced and were evaluated under the International *Musa* Testing Programme (IMTP). These varieties were tested against black and yellow sigatoka, fusarium wilt and nematodes. Information on pathogen populations, host-pathogen relationships and adaptability and productivity were obtained through the evaluation trials (Table 2). Currently, IMTP is on its Phase III, and is being undertaken in several countries.

To enhance a broader national evaluation trials in Asia Pacific, INIBAP established the National Repository, Multiplication Centers (NMRDC) in all BAPNET-member countries. The NMRDCs are the repositories of both popular local as well as introduced improved varieties from INIBAP-ITC. All germplasm movements, both into the region from outside and between countries in the region, are carried out according to the FAO/IPGRI Guidelines for the Safe Movement of *Musa* Germplasm. Appropriate Material Transfer Agreements were signed to cover the introduction of all INIBAP-IMTP varieties. Support has been provided to access the new, improved hybrids and superior varieties from INIBAP and multiply them locally, in order to provide...
materials to national programmes for more expanded evaluation activities and eventual adoption by farmers. Local tissue-culture facilities are being used for multiplying planting materials.

A follow-up project to the NRMDCs is the Evaluation and Promotion of *Musa* Germplasm (EPMG). This is already being started in several countries through the establishment of on-station and on-farm experiments.

**Table 2.** List of hybrids available for evaluation in IMTP Phase III.

<table>
<thead>
<tr>
<th>Hybrid</th>
<th>Type</th>
<th>Characteristic*</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHIA-01</td>
<td>Dessert/cooking</td>
<td>Resistant to BS and FW</td>
</tr>
<tr>
<td>FHIA-02</td>
<td>Dessert/cooking</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>FHIA-03</td>
<td>Dessert/cooking</td>
<td>Resistant to BS and FW, drought tolerant</td>
</tr>
<tr>
<td>FHIA-17</td>
<td>Dessert/cooking</td>
<td>Tolerant to BS and resistant to FW race 1.</td>
</tr>
<tr>
<td>FHIA-18</td>
<td>Dessert</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>FHIA-21</td>
<td>Plantain</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>FHIA-23</td>
<td>Dessert/cooking</td>
<td>Tolerant to BS and FW</td>
</tr>
<tr>
<td>FHIA-25</td>
<td>Cooking</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>SH-3640</td>
<td>Dessert/cooking</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>BITA-2</td>
<td>Cooking</td>
<td>Resistant to BS, Susceptible FW</td>
</tr>
<tr>
<td>BITA-3</td>
<td>Cooking</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>CRBP-39</td>
<td>Plantain</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>SH-3436-9</td>
<td>Dessert</td>
<td>Tolerant to BS</td>
</tr>
<tr>
<td>IRFA-911</td>
<td>Plantain</td>
<td>Resistant to BS</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>Dessert</td>
<td>Resistant to FW race 1</td>
</tr>
<tr>
<td>GCTCV-106</td>
<td>Dessert</td>
<td>Resistant to FW race 1</td>
</tr>
<tr>
<td>GCTCV-247</td>
<td>Dessert</td>
<td>Resistant to FW race 1</td>
</tr>
<tr>
<td>‘Yangambi km 5’</td>
<td>Dessert/cooking</td>
<td>Reference clone (sigatoka)</td>
</tr>
<tr>
<td>‘Pisang Ceylan’</td>
<td>Dessert</td>
<td>Reference clone (sigatoka)</td>
</tr>
<tr>
<td>‘Gros Michel’</td>
<td>Dessert</td>
<td>Reference clone (fusarium)</td>
</tr>
<tr>
<td>‘Williams’</td>
<td>Dessert</td>
<td>Reference clone (fusarium)</td>
</tr>
<tr>
<td>‘Cultivar Rose’</td>
<td>Dessert</td>
<td>Reference clone (fusarium)</td>
</tr>
<tr>
<td>‘Cachaco’</td>
<td>Cooking/dessert</td>
<td>Reference clone (fusarium)</td>
</tr>
<tr>
<td>‘Pisang Jari Buaya’</td>
<td>Dessert</td>
<td>Reference clone</td>
</tr>
</tbody>
</table>

* BS = black sigatoka  FW = fusarium wilt
The IMTP, NRMDCs and EPMG: Instruments to enhance the maintenance, multiplication, distribution, evaluation and promotion of *Musa* varieties in Asia and the Pacific

Inge Van den Bergh*, Marian Angeli G. Maghuyop, Jean-Vincent Escalant and Agustin B. Molina, Jr.

Bananas and plantains are among the major fruit crops in the world, but their production is seriously threatened by many pest and disease problems, among which are black and yellow sigatoka, fusarium wilt and nematodes. The members of BAPNET have identified pests and diseases as the main constraint to *Musa* production in Asia and have appealed to INIBAP to mobilise resources to address such constraints. Different institutions began banana breeding programmes to overcome these diseases, and a number of high-yielding, pest- and disease-resistant varieties were developed. Although the major *Musa* breeding programmes are located outside Asia, many of the new hybrids being produced by these programmes may be of interest for production in Asia.

The *International Musa Testing Programme* (IMTP) is a world-wide collaborative effort coordinated by INIBAP to evaluate, in multi-locational trials around the world, such elite *Musa* varieties produced by breeding programmes as well as promising germplasm accessions from the INIBAP collection, in order to obtain information on their resistance/tolerance to black and yellow sigatoka, fusarium wilt and nematodes. The aim is to identify banana and plantain hybrids resistant to these pests and diseases, which would meet local requirements and with which small-scale farmers could replace existing susceptible cultivars.

**IMTP phase I** - The establishment of IMTP began in 1989 as a programme to evaluate germplasm from the FHIA-breeding programme in Honduras for resistance to black sigatoka. Seven tetraploid hybrids with wide genetic backgrounds were tested along with several diploid reference clones (both wild and edible), that represented the whole range of reaction to black sigatoka, from highly

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resistant to highly susceptible. The experiments were established in six countries.

Four years later, the recommendation was made to release three clones for distribution: the clones FHIA-01 and FHIA-02, both dessert banana varieties with outstanding performance and high resistance to black sigatoka, and FHIA-03, a cooking banana also with excellent performance and resistance to black sigatoka. Over the last ten years, these three clones have been distributed to more than 50 countries worldwide.

**IMTP phase II** – The second phase of IMTP started in 1996. The germplasm was evaluated for resistance to three diseases instead of one: black sigatoka, yellow sigatoka and fusarium wilt. Four breeding programmes contributed germplasm and the number of testing sites increased from six to 37, despite the fact that the trials were financed at the participating institutes’ own expense.

The results suggested that, among the different materials tested, FHIA-23 and SH 3436-9 are the most tolerant to black sigatoka. They also performed well in terms of yield, and the good performance of the FHIA and INIVIT hybrids compared to local references was reinforced. In conclusion, the FHIA hybrids were consistently the best yielding genotypes in these trials. The improved hybrid with the best overall performance was FHIA-23. An improved cultivar that deserves special reference is GCTCV-119, which had the lowest discoloration score for both Foc races and good yields under good management.

**IMTP phase III** – At the moment, 27 countries (Australia, Bangladesh, Burundi, Cameroon, China, Colombia, Costa Rica, Côte d’Ivoire, Dominican Republic, Ethiopia, Haiti, Honduras, India, Indonesia, Malaysia, Mexico, Nicaragua, Peru, Philippines, Rwanda, Sri Lanka, South Africa, Taiwan, Thailand, Uganda, Venezuela and Vietnam) are participating in IMTP phase III.

Evaluation guidelines are made available to the participating programmes and a standard procedure for data management and statistical analysis has been developed. Selected hybrids/varieties are recommended by INIBAP for further evaluation and distribution to farmers.

In the course of 2001, some 450 assignments of germplasm accessions have left the INIBAP Transit Centre (ITC) destined for the countries taking part in phase III of IMTP. These include dessert and cooking bananas and plantains, either resistant or tolerant to black sigatoka and fusarium wilt, as well as reference clones to the three diseases. These are FHIA-01, FHIA-02, FHIA-03, FHIA-17, FHIA-18, FHIA-21,

In addition to the release of elite banana materials, integrated pest management (IPM) strategies for many of the important banana pests and diseases have been developed, including the use of in-vitro plantlets as clean planting materials.

However, the existence in itself of these elite banana materials and IPM strategies is not sufficient to help small-scale farmers address the serious constraints they face from pests and diseases. In order to obtain a rapid and significant impact on banana production levels, and thus on rural poverty and malnutrition, small-scale farmers need to get access to the available elite materials and the developed strategies. The availability of in-vitro propagated materials of these improved varieties for wide distribution is limited by the capability of the International Transit Centre (ITC) in Belgium to respond to the many requests for materials worldwide. In this perspective, BAPNET launched the program of the National Repository, Multiplication and Dissemination Centers (NRMDCs) in Asia and the Pacific, to provide access to the new, improved hybrids and superior varieties developed by breeding programs all over the world, multiply them locally, and make them available to Asia and Pacific countries for national yield performance evaluation by researchers/farmers and eventual adoption by farmers.

The NRMDCs, the ITC in Belgium and the breeding programmes worldwide exchange local germplasm and improved hybrids. The NRMDCs maintain this germplasm and distribute clean materials of all germplasm to scientists, farmers and other interested local parties. These parties, in return, give feedback on the performance of all the varieties to the NRMDCs, ITC and the breeding programmes.

The goals of the NRMDCs are:
- improved access to new hybrids and superior varieties from INIBAP;
- local multiplication for provision of materials to national programmes for more expanded evaluation activities;
- local multiplication for provision of materials for the eventual adoption by farmers; and
- maintenance of disease-free foundation stocks.

Twenty-three accessions were turned over to the participating institutes of BAPNET member countries and institutions. Most of the institutes requested in-vitro proliferating tissues. Rooted materials were sent only to those institutes where the facilities for in-vitro culture were not
adequate. Some institutes experienced some problems with contamination and some of the accessions needed to be replaced.

The main activities of the NRMDCs are conservation of the introduced and local varieties under *in-vitro* conditions as well as in a screenhouse and field, multiplication and distribution of the germplasm to scientists and farmers, and evaluation and promotion of the *in-vitro* propagated banana materials.

In May 2004, a questionnaire to assess the impact of the NRMDCs after 3 years of implementation was sent to the partners.

The BAPNET partners unanimously agree that the NRMDCs are an efficient tool for the conservation and maintenance of germplasm. All but SPC also value the importance of the NRMDCs in the evaluation of germplasm. SPC has no land available for the evaluation of the material and has to rely on its member countries for field testing.

Some partners also consider the NRMDCs efficient in the multiplication and distribution of germplasm. However, the capacity of the NRMDCs in some countries is too low for the supply of materials on a large scale. Possible cooperation between the NRMDCs and government institutions, private companies or NGOs is suggested. This is in fact already being done in the Philippines. For its programme of distribution of local and introduced varieties to State Universities and Colleges (SUCs) as well as small-scale farmers in the Philippines, INIBAP has called upon the services of a private company that supplies INIBAP with large numbers of meriplants at a minimal cost of less than $0.1 per plantlet. Whenever the SUCs or farmers are not able to raise the meriplants themselves, private nurseries take over the job of raising the plantlets until ready for field planting.

The major strengths of the NRMDCs were identified as follows:

- enrichment of the genetic material through the introduction and distribution of new varieties;
- introduction of the technique of using *in-vitro* propagated plantlets as disease-free planting materials;
- supply of materials for experiments; and
- safety conservation of germplasm.

Despite the enthusiasm of most partners, the NRMDCs are not perfect yet. There is a need for the improvement of the facilities as well as human resources in order to enhance the institutional capacity of the NRMDCs. SPC would benefit from the availability of more germplasm at the beginning, which would assist multiplication for large-scale distribution. ICHORD and VASI mentioned that the networking within
and between countries could still be improved. Lastly, promotional campaigns and dissemination of information, both on the NRMDCC and the new varieties, is regarded of high priority, certainly by ICHORD and BPI.

During the evaluations carried out by many of the NRMDCs, the introduced varieties performed better than the local varieties in most trials in terms of agronomic features and yield. In general, they also show a good resistance/tolerance to pests and diseases. The postharvest characteristics and taste however proved to be different from the local varieties. Consumers still have to get used to the unfamiliar taste and as a result, farmers adopt a “wait-and-see” attitude towards growing these varieties. It was suggested that promotional campaigns could be of much help to overcome this problem.

Most farmers are impressed by the technique of using in-vitro propagated plantlets. For them, the main advantages over traditional planting materials are that in-vitro plantlets are free of pests and diseases, give a uniform growth and are easy to transport. However, the biggest obstacle that discourages farmers to use in-vitro materials is its higher price compared to suckers.

In 2004, the NRMDC programme was concluded in BARI, CARDI, GAAS, SCAU, NRCB, ICHORD, MARDI, BPI, IPB, HORDI, HRI, VASI and SPC. The countries where the programme started more recently (CATAS, MAS, PNG and TBRI) will complete the program in 2005. However, the NRMDCs will still continue to play an important role in the production of pest- and disease-free planting materials, whether it be from local or introduced germplasm. Cooperation with other institutions may be recommended here.

Because of the success of the programme and the interest of most partners to continue and further elaborate the NRMDCs, a follow-up project to evaluate and promote Musa germplasm within the countries through the establishment of on-station and on-farm experiments was developed. The Letter of Agreement was signed by all partners and the EPMG programme was initiated already in several countries.

Note: All germplasm movement, both into the region from outside and between countries in the region, is carried out according to the FAO/IPGRI Guidelines for the Safe Movement of Musa Germplasm.

References


Safe exchange of *Musa* germplasm, knowledge of the genome and its application in *Musa* improvement

Ines van den Houwe, Nicolas Roux*, Jean-Vincent Escalant and Richard Markham

Conserving and managing diversity

Activities in the conservation and management of banana genetic diversity are centred on the state-of-the-art International *Musa* Germplasm Collection managed by INIBAP at the INIBAP Transit Centre (ITC) in K.U.Leuven* with the support of the Directorate General for Development Cooperation of Belgium. Most of the collection is held ‘in trust’, under the auspices of the FAO for the benefit of the international community and is made publicly available through a standard material transfer agreement (MTA). A major upgrade of the collection, funded by the World Bank and Gatsby Charitable Foundation, is underway to rejuvenate and validate the taxonomy of the *in vitro* collection and to place the entire collection in safe, long-term storage in liquid nitrogen (cryopreservation). Advances in germplasm conservation, and cryopreservation in particular, have helped place INIBAP and K.U.Leuven in a position where they can provide expertise or capacity building to other genebanks. Other activities include the management of data on *Musa* accessions worldwide, research into viral diseases and the molecular and morphological characterization of the accessions.

Collecting

- In January, Prof. Edmond De Langhe conducted a consultancy mission in the Democratic Republic of Congo to plan collecting missions of plantain cultivars in the eastern Congo basin.
- Preparations were made at the field collection at the University of Kisangani to house the cultivars that will be collected in 2005. The collection will be expanded to include plantains from the Congo Basin that are not found in the field collections held at CARBAP and IITA, namely dwarf, semi-dwarf, early fruiting and drought resistant cultivars.
- A workplan for maintaining the field collection has been developed and the areas for conducting collections has been identified.

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Conservation

- There are currently 1177 accessions being maintained under slow growth conditions (MTS) in the genebank (of which 986 are held 'in trust').
- Seven accessions received from Oman in 2003 were officially transferred to the ITC collection in 2004.
- In the course of 2004, 1245 accessions were removed from cold storage for annual subculturing. The cultures were checked for fungal contamination and viability and only the suitable ones were used to establish a fresh set of 20 proliferating shoot cultures.
- Started in 2001, work on rejuvenating the collection –whereby samples are regenerated, the plants grown in greenhouses and then decapitated to supply suckers –continued. In 2004, 106 accessions, including 89 accessions that were planted for the first time and 17 accessions that needed replanting because the plants had died after planting or after decapitation, were transferred to greenhouses where the vigour and morphology of the plants are checked every 2 months. During the same period, 224 accessions were returned in MTS.
- In 2004, 358 accessions have been sent to field sites in Cameroon (173), Guadeloupe (43), Honduras (46), the Philippines (69) and Uganda (27) for evaluating their trueness-to-type.
- An agreement has been drawn up with Universiti Putra Malaysia to cryopreserve zygotic embryos from wild banana species.
- K.U.Leuven continued to work with Infruitech-Nitvoorbij in South Africa and CIBE-ESPOL Ecuador to cryopreserve the collection. As of the end of 2004, 306 banana accessions had been cryopreserved at K.U.Leuven, 4 at Infruitech and 10 at ESPOL. The arrival at ESPOL of plant material from the ITC was delayed by formalities, while progress at Infruitech was hindered by a bacterial contamination that could not be eradicated.
- Research into the cryopreservation protocol for proliferating meristems using the simple freezing method showed that for the cultivars ‘Cacambou’, ‘Grande Naine’ and ‘Williams’, the rate of shoot regeneration increased after the application of 0.1 to 0.5 mM cholesterol, sitosterol or stigmasterol to the sucrose preculture medium. The post-thaw regeneration frequencies using the vitrification method were not affected by the addition of sterols.
- In general, the addition of 1 mM of polyamines and aromatic amines to the preculture or regeneration medium did not affect post-thaw shoot regeneration of banana meristems. The addition
of tyramine to the preculture medium enhanced the rate post-thaw shoot regeneration of ‘Cacambou’ and ‘Williams’ using the simple freezing method.

- A technician has been recruited by K.U.Leuven and trained in cryopreservation to start work on a ‘black box collection’ that will serve as insurance against the physical loss of the collection in Leuven.

- The management of the collection has been made easier with the installation of a data management system that records most aspects of accession information, from virus indexing results to stock levels. The information is accessed from a hand-held unit that reads the barcodes attached to each accession. All the accessions have been bar-coded and the data for these accessions are now routinely entered in the database by means of this device. Improvements are being made to the system, which will also facilitate the exchange of information with MGIS.

- In response to demands for DNA, the ITC developed a freeze drying protocol and established a collection of lyophilized leaf samples, which means that even virus-infected accessions can be made available for molecular study. In 2004, 465 samples of 63 rejuvenated accessions have been lyophilized. Each sample consists of ±1g of fresh leaf tissue (or 0.1g of lyophilized tissue) and is kept in an air- and water-tight plastic bag that is stored in a freezer at -20°C. The leaf samples will be made available in 2005.

Characterization

- The Laboratory of Molecular Cytogenetics and Cytometry at the IEB finished determining the ploidy level of the 1150 accessions held at the ITC at the end of the project. Flow cytometry was used. The method measures the content of nuclear DNA, which is directly proportional to the number of chromosomes. The analysis confirmed the ploidy of 958 accessions and revealed the level of 81 accessions for which it was unknown (Figure 1). The ploidy turned out to be different from the previously accepted level in 88 accessions. The exercise confirmed that maintaining plants under in vitro conditions does not lead to large-scale changes in the genome.

- The characterization activities funded by the Challenge programme for “Unlocking genetic diversity in crops for the resource-poor” are presented in the section on the Global Musa Genomics Consortium.

- As part of an IFRA-funded project, the genetic diversity in 15
populations of *Musa balbisiana* from China was studied by using AFLP. High levels of genetic diversity were revealed. The application of AFLP to 281 plants generated 199 bands.

- In another IFRA-funded project, microsatellites have been used to differentiate 10 FHIA hybrids in order to facilitate their identification and the conservation of the true types. Ten microsatellites were enough to discriminate between FHIA-01 and FHIA-18 but not the other hybrids.

**Figure 1.** Distribution of 1150 *Musa* accessions in relation to their ploidy level before and after flow cytometry analysis. Mixoploidy refers to a plant containing cells of different ploidy (e.g. 2x+3x). Mixed ploidy refers to accessions represented by plants of different ploidy.

**Dissemination**

- In 2004, a total of 919 accessions, represented by 3425 tissue culture samples, were sent by the ITC to 32 countries, which is 33% more than in 2003. The increase is mainly due to the start, in 2004, of the field verification activity as part of the rejuvenation of the collection.

- The majority of samples (64%) were sent as rooted plantlets.

- In 2004, 8 accessions were supplied to the QDPI Virus Indexing Centre in Australia and 9 to the Cirad one in France. No indexing results were released this year. The proportion of virus-free plants and virus-infected ones is presented in Figure 2.
Virus research

- As part of a World Bank-funded project, the Faculté des Sciences Agronomiques de Gembloux (FUSAGx) has shown that a protocol based on thermotherapy combined with meristem isolation to be the most efficient method to eliminate the BanMM virus, which infects 18% of the collection. Routine eradication of the BanMM virus started in 2004. Of the 100 or so accessions needing treatment, 5 rooted plants of the first 20 accessions have been sent to FUSAGx.

- Plantlets that test virus-negative are returned to the ITC, where a new set of proliferating cultures is established from a clean plant and 5 rooted plants are prepared for full virus indexing at one of the VICs. The entire process will take about 1.5 year.

- PPRI developed a triple antibody sandwich (TAS) ELISA test capable of detecting a wide range of BSV isolates.

- Work was initiated on a survey of molecular diversity of BSV in Colombia, Ecuador, Costa Rica and Mexico to provide data for risk assessment. Thirty samples have been sent from Colombia to CINVESTAV in Mexico to be tested.

- Cirad scientists studying the effect of in vitro culture on BSV activation have observed that BSV(-) material containing the B genome could give rise to infected clones following in vitro multiplication. This work needs to be pursued with monitoring the virological status in the field of plants that have been indexed as BSV(-) and testing the impact on activation of multiplication techniques such as PIF.
MGIS

- A total of 5174 accessions from 17 institutions are included in the MGIS database.
- The MGIS database is now linked to the SINGER database – the CGIAR System-wide Information Network for Genetic Resources.
- The taxonomical experts Edmond De Langhe and Markku Hakkinen will help check the classification data in the MGIS database.
- As part of the upgrading of the MGIS database, it is being linked with the ITC genebank management system.

Using diversity for genetic improvement

INIBAP works on genetic improvement at multiple levels to address global research challenges collaboratively. INIBAP’s support to crop improvement focuses on broadening the genetic base of materials available to banana and plantain breeders around the world, facilitating interactions between breeders, encouraging interactions with specialists in pests and diseases, and helping breeders to achieve the widest possible evaluation and uptake of the improved materials resulting from their work. Molecular techniques are becoming increasingly important in understanding the diversity in the *Musa* genome, how it functions, and how it can be used in crop improvement. Much of this agenda is pursued through consortia for which INIBAP provides the secretariat (see below). The Generation Challenge Programme has provided an impetus to research in this area and the Global *Musa* Genomics Consortium has already played a key role in bringing together research groups working on *Musa* to develop a coherent response to this new opportunity.

International Musa Testing Programme

In the IMTP, INIBAP facilitates the testing of new improved banana varieties in locations around the world. After a decade of functioning, IMTP is in its third and most ambitious phase yet. Thirty-five varieties, including promising improved varieties from all six major banana breeding programmes, have been disseminated to and are being evaluated by 50 partners in 35 countries in phase III of IMTP. For the first time, two private companies in Asia have participated in the trials. The participating countries are Australia, Bangladesh, Burundi, Cameroon, China, Colombia, Costa Rica, Côte d’Ivoire, Dominican Republic, Ethiopia, Haiti, Honduras, India, Indonesia, Malaysia, Mexico, Nicaragua, Peru, Philippines, Rwanda, South Africa, Sri Lanka, Uganda, Venezuela, Vietnam.
Support to breeding programmes

- Two populations segregating for nematode resistance supplied by CIRAD have been evaluated in the field at CORBANA, Costa Rica.
- New hybrids from CARBAP, in Cameroon, have been sent to the ITC in Belgium for virus indexing and further evaluation.

Developing improved East African highland banana varieties using biotechnology

In 2000, in response to a request from the Ugandan Government and USAID, INIBAP set up a project to develop improved AAA East African highland bananas (EAHB) through the use of biotechnology. The aims were to genetically modify eight cooking and brewing varieties to express resistance to nematodes, black sigatoka and weevils, and to build Uganda’s national capacity to use the current tools of biotechnology to develop high-yielding, pest- and disease-resistant varieties of this crop. Two laboratories for tissue culture and molecular research at NARO have been revamped and furnished and a team of technicians has been trained and guided through the process of establishing ECS with technical backstopping from KULeuven, CIRAD and JIC.

Donor: Ugandan Government, USAID, Belgian Government, Rockefeller Foundation

Partners by country: Belgium: K.U.Leuven; France: CIRAD; South Africa: FABI-University of Pretoria; Uganda: IITA, Makerere University, NARO UK: JIC

- Given the difficulty of reproducing the ‘scalp’ technology using EAHB cultivars, it was decided in 2004 to concentrate on male flowers. The male flowers of four of the eight originally selected cultivars – ‘Mbwazirume’, ‘Nakinyika’, ‘Nakitembe’ and ‘Mpologoma’ – are regularly used as starting material to initiate cell suspension cultures.

- Embryogenic calli have been obtained for ‘Mbwazirume’ and ‘Nakinyika’ and cell suspensions initiated.
The cell suspensions of the AAB cultivar ‘S. Ndizi’ continue to perform well.

Agrobacterium-mediated transformation of ‘S. Ndizi’ cell suspensions by using the GUS marker gene was performed, confirming the wide applicability of the Agrobacterium transformation system developed at KULeuven.

Equipment for cryopreservation was acquired and cryopreservation of cell suspensions started in February 2004. Seventeen cell lines have been cryopreserved, of which 13 were re-established in liquid medium. All the cell lines that established well in liquid medium (i.e. the cells multiplied and increased in volume) and maintained their embryogenic potential were less than 1 year old at the time of cryopreservation.

The inhibitory activity on banana weevils (Cosmopolites sordidus) of the papaya cystatin was enhanced by the generation of mutants with improved binding and stability (Figure 3). Based on an analysis of their amino acid sequences, 18 mutations were created and tested for their ability to inhibit papaya cystatins. In preliminary tests, inhibition was improved in 11 out of 18 mutant cystatins.

A technique allowing Radopholus similis and Pratylenchus coffeae to take up substances from a liquid medium has been developed. This will enable the testing of various lectins and, as such, the identification of potential genes to control nematodes.

A cDNA library was developed using plants artificially infested with weevil eggs and untreated plants. Various subtraction products were isolated and cloned. Inserts obtained after digestion with restriction enzymes were sequenced. The sequences seem to belong to family of variable genes that might be involved in resistance to weevils.

Figure 3. Papaya cystatins (insert) were re-engineered and fed to weevils. The larvae fed the modified cystatins had significantly reduced growth (right) compared to the controls (left).
Developing genetic transformation protocols

With funds from DGDC, INIBAP pursues studies to refine the protocols for developing and storing starting materials for genetic transformation and for optimizing the process of transformation. The research takes place in the Laboratory for Tropical Crop Improvement at KULeuven.

- In 2004, 13 cryopreservation experiments on 8 cell lines each were conducted. For each cell line, an average of 8 cryotubes were transferred to the liquid nitrogen tank. After careful screening of all cryotubes, 623 cryotubes remain stored for the long term. The total number of cryotubes stored in liquid nitrogen containing transformation competent cell lines of 13 cultivars is 2140 (Table 1).

- The conventional and new methods to prepare embryogenesis-competent explants were used on ‘Calcutta 4’, ‘Williams’, ‘Ingarama’, ‘Orishele’ and ‘Cachaco’. The quality of the cultures was scored from very low (-) to very high (+++) depending on the proportion of meristematic tissue to corm and leaf tissue. According to the time required to obtain 50 optimized multiple meristem cultures (i.e. cultures whose quality could not be further improved), the gain of time with the new method was 1 month for ‘Cachaco’, 3 for ‘Calcutta4’, 5 for both ‘Williams’ and ‘Ingarama’ and 6 for ‘Orishele’. The morphological characteristics of the cultures, however, were similar, except for ‘Calcutta 4’ and ‘Ingarama’, which were slightly improved using the new method.

- Several promoter tagging vectors containing the codon-optimized luciferase (luc) reporter gene close the right hand side border of the T-DNA have been developed. These constructs increased the activity of the luciferase enzyme and the tagging frequency 40-fold in ‘Three hand planty’, ‘Williams’ and ‘Cacambou’, compared to the wild-type luciferase gene. These constructs significantly increased the efficiency of the large-scale search for banana promoters. As a result, 40 000 cell colonies can be screened in a week.

- The 10 196 gene-specific tags generated from leaf cDNA after performing SuperSAGE represent 5292 expressed genes, of which 83% occurred only once, a very low frequency.

- Despite the poor results obtained when using xylose to select transgenic plants of ‘Three hand planty’, the xylA gene was further tested by introducing it into embryogenic cell suspensions of the dessert banana ‘Gros Michel’. The regeneration frequency was only improved when sucrose was added to the selection system. It was
concluded that xylose is not suitable for efficient selection of transgenic banana plants. Preliminary results also indicate that mannose and the phosphomannose isomerase gene are not suitable selection systems.

Table 1. Cryopreserved suspensions that are currently safely stored for the long term

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Genomic group</th>
<th>Number of independent cell lines stored in LN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agbagba</td>
<td>AAB plantain</td>
<td>4</td>
</tr>
<tr>
<td>Three hand plany</td>
<td>AAB plantain</td>
<td>6</td>
</tr>
<tr>
<td>Orishele</td>
<td>AAB plantain</td>
<td>10</td>
</tr>
<tr>
<td>Obino L’ewai</td>
<td>AAB plantain</td>
<td>1</td>
</tr>
<tr>
<td>Dominico</td>
<td>AAB plantain</td>
<td>2</td>
</tr>
<tr>
<td>Bisé egomé</td>
<td>AAB plantain</td>
<td>2</td>
</tr>
<tr>
<td>Bluggoe</td>
<td>ABB</td>
<td>6</td>
</tr>
<tr>
<td>Cacambou</td>
<td>ABB</td>
<td>16</td>
</tr>
<tr>
<td>Cachaco</td>
<td>ABB</td>
<td>5</td>
</tr>
<tr>
<td>Dole</td>
<td>ABB</td>
<td>8</td>
</tr>
<tr>
<td>Grande Naine</td>
<td>AAA</td>
<td>11</td>
</tr>
<tr>
<td>Gros Michel</td>
<td>AAA</td>
<td>1</td>
</tr>
<tr>
<td>Williams</td>
<td>AAA</td>
<td>24</td>
</tr>
</tbody>
</table>

PROMUSA

The Global Programme for Musa Improvement, PROMUSA, brings together more than 100 researchers to focus on the smallholder crop. Working groups are devoted to Sigatoka, Fusarium wilt, Nematology, Weevil, Virology and Genetic Improvement. Genomics consortia on banana and Mycosphaerella and a breeding consortium have also been launched. INIBAP provides the secretariat.

- The “First International Congress on Musa” organized by PROMUSA and MARDI took place in Malaysia from 6 to 9 July 2004. Some 250 delegates, from both public and private research institutes as well as from the commercial sector, participated in the Congress. The theme “Harnessing research to improve livelihoods” was chosen to illustrate PROMUSA’s commitment to knowledge building across disciplines and regions, which, in due course, should have a direct impact on improving the livelihoods of banana farmers and communities throughout the world.

- The 4th PROMUSA Global Meeting was held from 12 to 13 July 2004 in Malaysia. Each working group met to review scientific priorities and elect a convener.

- The convenors are: Dirk De Waele (Nematology); Jaroslav Dolozel, IEB (Genetic improvement); Andrew Geering, QDPI (Virology);
Global *Musa* Genomics Consortium

This Consortium brings together expertise from 30 public-funded institutions in 16 countries. As well as providing close collaboration, the consortium enables research resources to be shared, including sequence data and enabling technologies. The sequence data produced by the Consortium will be placed in the public domain and any new varieties will be made freely available to smallholder farmers. The overall strategy of the Consortium is to adopt a step-wise approach, focusing on comparative genomics and targeting gene discovery. INIBAP provides the secretariat. Funding is provided by the members through individual projects. Much of the Consortium activities are dependent on funding from the member institutes. Several regional groupings between members have also been established.

**Partners by country:** Australia: DPI, QUT, University of Queensland; Austria: ARC, FAO/IAEA; Belgium: K.U.Leuven, UCL, University of Gent; University of Liege, University of Gembloux; Brazil: CENARGEN/EMBRAPA, Universidade Catolica de Brasilia; Czech Republic: IEB; Finland: Turku Centre for Biotechnology; France: CIRAD, INIBAP; Germany: MIPS/GSF; India: IIHR; Japan: NIAS; Malaysia: UM; Mexico: CICY, CINVESTAV; Nigeria: IITA; Uganda; IITA-ESARC; UK; University of Leicester; USA: Arizona State University, NSF, TIGR, University of Georgia; University of Minnesota.

- The 3rd meeting of the Global *Musa* Genomics Consortium was held in Malaysia in July and was attended by 22 participants from 12 countries.
- KULeuven has been suggested as *Musa* Transgenic Resource Center for the Consortium, i.e. provide transgenic plants for partners with their gene of interest and coordinate with interested partners the generation and the utilization of a mutant population by T-DNA insertion.
- The CGIAR Generation Challenge Programme (GCP), which became operational in 2004, has provided support for Consortium member activities in genetic diversity characterization, comparative genomics and bioinformatics.

**Subprogramme genetic diversity:**

- A first set of 48 accessions represented at the ITC and Cirad field
collection in Guadeloupe was selected for genotyping using SSR and IRAP markers. The DNA was extracted at CIRAD and sent to IAEA and the University of Leicester.

- The University of Leicester team analysed the 48 accessions using IRAP markers. The results were comparable to the ones obtained using other DNA-based markers and were obtained at less cost.

- FAO/IAEA developed 53 SSR markers from a small insert library enriched for SSR motifs and from BAC-end sequences. The reliability of these markers is being tested with the 48 accessions selected by the Consortium.

- A second set of 186 accessions mostly from the IITA collection was selected. The DNA extracted at IITA was sent to CIRAD and molecular characterization is being done by at both institutes by using 27 SSR markers.

- The 4th FAO/IAEA Interregional Training Course on Mutant Germplasm Characterization Using Molecular Markers was held from 27 September to 22 October 2004 at the IAE in Vienna, Austria.

**Subprogramme comparative genomics:**

- The University of Leicester team designed primers using conserved regions of orthologous genes. Some 80 primer pairs have been constructed and 360 sequences identified. A picture of genetic variability between accessions and the extent of gene conservation between *Musa* and other species is emerging.

- To identify COS markers common to rice/sorghum and *Musa*, 49 cDNA clones from sorghum and rice were used at CIRAD to screen the *Musa acuminata* Calcutta 4 BAC library. The use of heterologous RFLP probes from sorghum is inadequate to create links between genetic maps of monocots.

- Two SSH cDNA libraries were constructed at CIRAD to better understand somaclonal variation and plant development.

- Gene expression profiling methods are being developed at IITA to identify markers for the selection of drought tolerant and high water use efficiency *Musa* accessions.

**Subprogramme bioinformatics:**

- INIBAP organized an EST analysis workshop, where 8 staff from member institutes in Brazil, India, Malaysia, Nigeria and France were trained to analyse their institute’s EST sequences. The genomic
data were made available in a web-based information portal on the Consortium web site. At the annual meeting of the GCP, special recognition was paid to INIBAP for its support to capacity building.

- A prototype, using the website technology BioMoby, has been developed to access the molecular characterization data in the CIRAD Tropgene online database using the accession identification number, effectively linking the passport data in MGIS with the molecular data in Tropgene.

- Laboratory Information Management Systems and a software for SSR genotyping were evaluated at Agropolis.

**Musa Genomics Resource Centre**

The *Musa* Genomics Resources Centre (MGRC) based at the IEB in the Czech Republic has been active in distributing *Musa* genome resources to consortium members and in developing new resources. The aim of the MGRC is to provide DNA libraries, individual DNA clones, markers for molecular cytogenetics and high-density colony filters to the members of the Consortium. Three BAC libraries are available through the MGRC as 384 or 96 well plates or as high-density colony filters and, exceptionally, as single clones (Table 2). A growing collection of repetitive DNA clones is also being maintained and characterized by copy number, genomic distribution in *Musa acuminata* and *Musa balbisiana*, and similarity to known DNA sequences. Cytogenetic markers available for distribution include those for 5S and 45S ribosomal RNA loci. New cytogenetic markers based on BAC clones isolated from genomic libraries are being developed.

A framework agreement is being prepared to consolidate the sharing of resources and information among Consortium members.

**Table 2. Features of the BAC libraries available through the MGRC.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Genotype</th>
<th>No. clones</th>
<th>Average insert size</th>
<th>Genomic coverage</th>
<th>Restriction site</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4BAM</td>
<td>Calcutta 4</td>
<td>17280</td>
<td>110kb</td>
<td>3x</td>
<td>BamHI</td>
<td>A.C. James and Q. Tao</td>
</tr>
<tr>
<td>MA4</td>
<td>Calcutta 4</td>
<td>55296</td>
<td>100kb</td>
<td>9x</td>
<td>HindIII</td>
<td>A. Villaninhos and P. Piffanelli</td>
</tr>
<tr>
<td>MBP</td>
<td>Pisang Klutuk Wulung</td>
<td>36864</td>
<td>135kb</td>
<td>9x</td>
<td>HindIII</td>
<td>J. Safař and P. Piffanelli</td>
</tr>
</tbody>
</table>
International Mycosphaerella Genomics Consortium

Partners by country: Brazil: EMBRAPA; Cuba: IBP; France: CIRAD; Mexico: CICY; Netherlands: PRI; Switzerland: ETH; and USA: BTI.

The International Mycosphaerella Genomics Consortium brings together seven partners from seven countries, who have shared research interest in Mycosphaerella species. Present activities aim to build a collection of Mycosphaerella isolates, mapping populations and transgenic strains at CIRAD, under the auspices of INIBAP, to be made available to the banana research community.

- The International Mycosphaerella Genomics Consortium members met in Malaysia on 9 July 2004. The development of a web site was discussed and it was proposed that the international collection of Mycosphaerella pathogens attacking bananas (M. fijiensis, M. musicola and M. eumusae) be based at CIRAD, under the auspices of INIBAP. The CIRAD collection already includes Mycosphaerella banana pathogens, as well as mapping populations and transgenic strains.

- IPB and the University of Hamburg are studying Mycosphaerella fijiensis-banana interactions, using cDNA libraries obtained from Calcutta 4 plants at an early stage of infection and from Niyarma Yik plants at a late stage of infection.

- At CIRAD-AMIS, three F1 populations were obtained by crossing isolates from Cameroon, Columbia, Mexico and the Philippines and are being screened using markers from M. fijiensis, M. grisea and M. graminicola.
Promoting conservation through sustainable use of underutilized crops in livelihood development - A case of buckwheat

Zongwen Zhang*

Underutilized crops are often considered ‘minor crops’ and were once grown more widely or intensively, but are falling into disuse for a variety of agronomic, genetic, economic and cultural reasons. Farmers and consumers are using these crops less because they are in some way not competitive with other species in the same agricultural environment (IPGRI 2002). Consequently, these species have been neglected and genetic erosion of their gene pools has become severe. Underutilized crops can be found in many different agricultural ecosystems, but they are mainly grown by small landholders in the marginal areas. They are usually characterized by having local importance in consumption and production systems, requiring relatively low inputs, adapting to specific agro-ecological niches, receiving scarce attention by national agricultural and biodiversity conservation efforts, mainly consisting of local types or landraces, and being cultivated with indigenous knowledge. Many underutilized species are adapted to low-input agriculture and depended on by a large number of people in marginal areas in developing countries. Millets, for example, are a staple food for people living in marginal dry areas in northwest China. The erosion of these species, whether wild, managed or cultivated, can have immediate consequences on the food security and well-being of the poor in marginal areas. Underutilized species are usually rich in nutrition. Many underutilized fruits and vegetables contain more vitamin C and pro-vitamin A than widely available commercial species and varieties (IPGRI 2002). Their enhanced use can improve nutrition. For example, buckwheat grains provide a rich source of high-quality nutritious food, high in amino acids, vitamin P, flavonoid rutin and dietary fibre. Similarly safflower oil contains 80% unsaturated fatty acid, of which 80% is linolic acid. Promoting use of underutilized crops will effectively maintain a diverse and healthy diet and to combat

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micronutrient dietary deficiencies in both developed and developing countries.

The growing demand from consumers in developed and developing countries for diversified foods is creating new market niches for underutilized species. These market opportunities can generate significant income for poor farmers in less-favoured environments where these crops have comparative advantages over other staples crops. Many underutilized crops are associated with local cultures and traditions. The diversity of underutilized crops provides diversity of food in taste, colour, texture and recipes prepared by different ethnic groups. Many underutilized crops have their greatest cultural value at the local level to support cultural diversity and maintain the colourful and enjoyable life of human beings in the world.

Buckwheat (Fagopyrum spp.) is an ancient Asian crop now widely grown around the world. Even though it is an underutilized crop, it remains important for food security in the temperate and hilly regions of countries in East Asia, East Europe and the Himalayan region (Arora 1995; Zhou and Arora 1995). Buckwheat contains rich amino acids, abundant vitamin P high in rutin, which reduces blood cholesterol; Vitamin B₁ and B₂, dietary fibre, lipids and minerals (Yang and Lu 1992; Ohsawa and Tsutsumi 1995). Traditionally, buckwheat was used as a nutritious food, a leafy vegetable, fodder or medicine in East Asian and South Asian countries. Nowadays, buckwheat has become an important health food. Buckwheat can be further processed to value-added products such as cakes, instant powder, wine or vinegar to increase the economic returns to the buckwheat farmers (IPGRI-APO 1999).

International Plant Genetic Resources Institute (IPGRI) Regional Office for Asia, the Pacific and Oceania (APO) has made efforts to promote the conservation and use of buckwheat genetic resources through a programme on underutilized crops in the region. The Programme aims at addressing constraints and promoting aspects of diversity availability, genetic enhancement and access to marketing. IPGRI-APO, in cooperation with the national programmes in the region, focused initially on producing a bibliography, descriptors and directory, and currently the emphasis is on in situ conservation, and assessing and promoting the potential of buckwheat for sustainable livelihoods for the poor.
Buckwheat biodiversity in APO region

Species diversity

Buckwheat belongs to the genus *Fagopyrum* and family Polygonaceae. There were 15 species in the genus *Fagopyrum*. Most of these species occur in the temperate areas of Eurasia and a few in North America. The classification of *Fagopyrum* was discussed by Ye and Guo (1992) and further improved by Ohnishi (1995). *F. esculentum* and *F. tataricum* are two cultivated species with rich diversity in East Asia and South Asia. Among the wild species, *F. cymosum* is widely distributed, *F. gracilipes* occurs in South China, extending to Bhutan, while other species namely *F. urophyllum*, *F. statice*, *F. leptopodum*, *F. leptopodum* var. *grossii*, *F. lineare*, *F. gracilipes* var. *odontopodum*, *F.caundatum* and *F. gilesii* are mainly located in South China with preponderance in Yunnan, Gunsu, Sichan and adjoining tracts (Ye and Guo 1992). The centre of species diversity is Southwest China, mainly northern Yunnan and southern Sichuan (Ohnishi 1995). The Himalayan region presents a diverse range of species including *F. esculentum*, *F. tataricum*, *F. kashmirianum*, *F. emarginatum*, *F. sagittatum*, *F. cymosum*, *F. megacarpum*, *F. gracilipes*. The Eastern Himalaya, particularly Nepal and Bhutan possess more diversity for the species of *F. sagittatum* and *F. kashmirianum*, which are co-specific with *F. esculentum* and *F. tataricum* (Arora 1995).

Genetic diversity

In Asia, particularly in China, Japan, DPR Korea, India and Nepal, efforts have been made to collect and conserve buckwheat genetic diversity. IPGRI-APO assessed the status of buckwheat genetic diversity collected and maintained in East and South Asia. It was estimated that 4711 accessions of buckwheat have been collected in East and South Asia, which account for about 52% of the world buckwheat collection. Furthermore, over 90% of the world tartary buckwheat accessions are from Asia. China has the largest buckwheat collection with 2146 accessions, which accounts for 46% of Asia’s total collections. India has 954 accessions, followed by Japan (746), DPR Korea (413), Nepal (327), R. Korea (95) and Mongolia (30) (Table 1). However, the diversity of wild species is not well represented in most of these collections. A total of 50 wild species accessions are maintained by China, Japan and India (IPGRI-APO 1999; Zhou and Zhang 1995).

Characterization of buckwheat genetic resources showed a wide range of diversity in common buckwheat characters such as seed size and...
Table 1. Buckwheat germplasm collections in Asian countries.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Common buckwheat</th>
<th>Tartary buckwheat</th>
<th>Wild buckwheat</th>
<th>Total accessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1544</td>
<td>578</td>
<td>24</td>
<td>2146</td>
</tr>
<tr>
<td>Japan</td>
<td>588</td>
<td>140</td>
<td>18</td>
<td>746</td>
</tr>
<tr>
<td>India</td>
<td>637</td>
<td>309</td>
<td>8</td>
<td>954</td>
</tr>
<tr>
<td>DPR Korea</td>
<td>405</td>
<td>8</td>
<td>413</td>
<td></td>
</tr>
<tr>
<td>Nepal</td>
<td>160</td>
<td>167</td>
<td>327</td>
<td></td>
</tr>
<tr>
<td>R. Korea</td>
<td>95</td>
<td>95</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>Mongolia</td>
<td>30</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3459</strong></td>
<td><strong>1202</strong></td>
<td><strong>50</strong></td>
<td><strong>4711</strong></td>
</tr>
</tbody>
</table>

shape, pericarp colour, flower colour, plant height, leaf size and shape, growth period, chemical components, etc. The evaluation is focused on identifying buckwheat lines with economically important traits such as early maturity, resistance to frost and lodging, high yield, reduced shattering and high flavonoid content. Genetic diversity of buckwheat has contributed to developing many buckwheat cultivars in the world (Campbell 1997).

Potential of buckwheat biodiversity in sustainable livelihood

Factors influencing farmers’ choice of buckwheat

Social and cultural values

Buckwheat is a very important crop for people living in remote areas in some countries in the region. For example, tartary buckwheat has been cultivated since the 2nd century B.C. and is one of the earliest food crops cultivated by Yi people in China. In Yi’s written language, tartary buckwheat is called “E’amu”. “E” means tartary buckwheat and “amu” means mother. Tartary buckwheat can always be found in any celebration of Yi in China. The flour of buckwheat is used in different religious festivals by making various processed products in Nepal. Some of the Lama’s monks (Gumba) also use it for social or religious purposes.

The value for food security and better nutrition

Buckwheat is a stable food crop in some areas of China. In the Liangshan Prefecture, Sichuan province of China, the tartary buckwheat growing area is about 30% of the total area planted with food crops. Tartary buckwheat is used for the preparation of baby food, bread, pancakes, thick porridge, for making sausages and other locally
consumed food products in Nepal. The tartary buckwheat is also used for preparation of local wine and whisky in both China and Nepal. In Dolpa, Nepal, buckwheat is the only crop which can provide food security to farmers.

Buckwheat grain contains 10.9-15.5% protein, 2.1-2.8% fat, 63-71.35% starch and 1.0-1.61% fibre (Chai et al. 1989). Protein content in buckwheat flour is significantly higher than that in rice, wheat, and maize. Its protein composition is similar to that of beans, i.e. high in albumin and globulin. It is also high in essential amino acids such as lysine (5-7%) that are deficient in major cereal crops, and lipids, minerals (iron, phosphorus, and copper), and vitamins (B1 and B2, VPP, VP and folic acid contents are all higher than in grains of major crops) and rutin. Rutin is only found in buckwheat grains and plants (but not in other grains (http://dreampharm.com/zrutin.asp). It contains more fat than rice and wheat. It contains 9 types of aliphatic acids, mainly oleic acid and linolic acids.

**Medicinal value**

Specific medicinal properties of buckwheat are mainly conferred by its biological flavonoid and fagopyritol. Flavonoid helps in relieving coughs and eliminating phlegm. Flavanoid content is higher in tartary buckwheat than common buckwheat. Using the flavonoid extracted from tartary buckwheat, several kinds of Chinese pharmaceutical preparations have been developed, including capsules, tablets, and elettuarie. Rutin has a function of preventing haemorrhage caused by fragile blood capillaries and treating hypertension by lowering sugars and lipids. Buckwheat contains abundant Cu, which can improve the function of Fe and prevent hypohemia.

**Process for adding value to products**

Processing could add more value to buckwheat products and generate more profit for farmers. For example, farmer He Zengbao from Pingtou town processed 10 t of buckwheat flour from 15 t of buckwheat grain and sold it in markets in Yuci and Yangqu. The value increased from US$2 012.25 to US$3 022.75, about a 33.4% increase in profit.

**Buckwheat flour or broken grains**

Examples of products from buckwheat flour and grain are common buckwheat flour, tartary buckwheat flour, dried noodles, instant noodles, dumpling, powder, flake, etc. The flour and grain products are easy to produce and are also durable for transportation. Therefore,
these products can be produced by community-run factories and sold to local markets.

**Buckwheat snacks**
This includes different kind of cakes made from buckwheat flour, for example, braised cake buckwheat cake, buckwheat-blood cake, etc. These products are mainly produced by food companies in nearby cities and supplied to the supermarkets.

**Buckwheat liquids**
Buckwheat is also used to produce wine and vinegar, which are usually produced by local factories and preferred by local people. Some of these products can be found in supermarkets in the cities. There could be a potential for expansion of the market for these products.

**Buckwheat tea**
Tartary buckwheat can be processed into different kinds of teas, which have functions of reducing blood pressure and lowering sugars and lipids. It can be processed by mixing with other materials such as the fruit of Chinese wolfberry (*Lycium* spp.).

**Market for income generation**
Buckwheat has become one of the main income sources of farmers in buckwheat producing areas. The survey in China showed that farmers gain much more growing buckwheat than growing other cereal crops. Domestic demand for buckwheat has increased dramatically in recent years while international markets remain stable. Some countries such as Japan import buckwheat from China. This provides an opportunity to expand buckwheat production and its economic value.

**Domestic market**
Generally, buckwheat can be grown even in poor soils and low inputs. China is a large buckwheat producing country with a total planting area of 1 million ha and a production of 1.05 million tonnes. Common buckwheat is planted on 0.7 million ha with a production of 0.75 million tonnes and tartary buckwheat on 0.3 million ha with a production of 0.3 million tonnes. A large proportion of buckwheat production is consumed by farmers themselves. However, considerable amounts are made available to the local market. There are specific companies and retail chain stores for buckwheat products in Beijing, Shanghai and other developed districts.
International market

One of the driving forces for buckwheat’s market growth is an increased demand from Asian market. Japan now imports approximately 120,000 tonnes of buckwheat annually for its soba noodles. Being low in fat and sodium with no cholesterol, buckwheat is also quite popular among health-conscious Americans. Annually, China exports 80,000 tonnes of buckwheat to Japan. In addition, China also exports buckwheat to the Netherlands, R. Korea, Hong Kong, Russia and Cuba. With an increase in health consciousness worldwide, demand is expected to grow, which has potential for farmers to grow more buckwheat and benefit from it.

Livelihood framework on buckwheat

The objective of developing a livelihood framework is to ensure a better livelihood for the poor. Plant diversity can be used to reduce poverty. The livelihood framework on buckwheat is to use buckwheat as a resource to improve the capital assets of buckwheat producers at selected sites. According to the study in Shouyang, Shanxi, the livelihood framework on buckwheat can be envisaged in Figure 1.

The framework brings different stakeholders together for promoting buckwheat production, processing and marketing. The Shouyang Buckwheat Association plays a critical role in linking different sectors. Members of the Association include farmers, enterprises, research organizations and governmental agencies. The Association is actively
involved in training farmers on buckwheat cultivation, sharing technologies, providing market information, introducing varieties, technologies and capital as well as coordinating member’s activities on production, process and marketing.

Farmers are the major players in buckwheat production and management of buckwheat genetic resources. They are major suppliers of raw materials to enterprises for processing new buckwheat products. Farmers’ traditional knowledge on the use of buckwheat will be useful information for enterprises in developing new buckwheat products. Farmers can benefit in two ways: 1) increased buckwheat productivity and 2) increased market opportunities for income generation. Farmers actively participate in variety selection for high yielding and good quality, which contributes to a better harvest and higher price.

Community enterprises play a role in adding more value to buckwheat products. The studies showed that processed flour could increase 191.2% the original value of buckwheat grain, while processed Bowl Shaped Lump could increase 883% the original value of buckwheat flour. At the same time, the processing of buckwheat also provides employment opportunities, which is an important source of income generation for farmers. The enterprises will pay attention to expanding market for seeking economic benefits. They also collaborate with scientists to develop new varieties of buckwheat to be used as health food.

Research organizations contribute to conservation and improvement of buckwheat genetic resources and make them available to farmers. In previous years, the research institutes have released 6 varieties of common buckwheat (Jinqiao No. 1, Xinnong No. 1, 8802-1, Pingqiao No. 2, Liuqiao No. 1, Yuqiao-4) and 10 of tartary buckwheat (Nongda 9909, ding 98-1, Dianning 1, Zhaoku 1, Qianwei 3, Jiujiang Kuqiao, Liuqiao-1, Liuqiao-2, Liuqiao-3 and Heifeng No. 1). In addition, scientists from food processing institutes help community enterprises to develop new buckwheat products such as tartary buckwheat wine and instant health thick soup of buckwheat. These new products are now available in the market in Shanxi Province.

Local government plays a role coordinating activities and providing policy support through its relevant departments. Government helps to facilitate the development of buckwheat markets and the establishment of buckwheat production bases. The government also will play a role in public awareness of buckwheat and its products.
Conclusion

Buckwheat has a long history of cultivation. It is mainly distributed in the Himalaya region covering East and South Asia and is an important crop for people living in the mountainous and remote areas in these regions. The Southwest of China is the original centre of cultivated species of *Fagopyrum*, where a diverse gene pool exists, including cultivated, semi-wild and wild species. The genetic diversity of buckwheat is mainly preserved in Asian collections, which are maintained at different *ex situ* genebanks. A wide range of diversity was found in buckwheat characters such as seed size and shape, pericarp colour, flower colour, plant height, leaf size and shape, growth period, chemical components, etc. Early maturity, resistance to frost, resistance to lodging, high yield, reduced shattering and high flavonoid content are major traits preferred by breeders for buckwheat improvement.

Buckwheat has great potential for supporting sustainable livelihoods in China. Buckwheat foods are well appreciated by a wide range of consumers not only in China, but also in many other countries such as Japan, Korea, etc. Buckwheat contains many nutritional components such as protein, amino acids, vitamin B1, vitamin B2, which are all important healthy compounds. Buckwheat also has medicinal value, particularly functioned by flavonoid in relieving coughs and eliminating phlegm, and prevention of haemorrhages and treatment of hypertension. For value adding, the production of food, health and medicinal products is essential for buckwheat producers and consumers. Many kinds of buckwheat processed flours, snacks, wine, and vinegars are available in local markets in China. Buckwheat is exported to international markets, particularly to Japan. This is an important source of income generation for local farmers. Through the livelihood framework developed on buckwheat, farmers, local processors and trade companies are all beneficiaries of buckwheat. This framework will serve as an example for other underutilized crops in the IPGRI-APO programme.

References


Promoting the conservation and use of underutilized and neglected crops. 19. Institute of Plant Genetics and Crop Plant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy


IPGRI-APO. 1999. Status reports on genetic resources of buckwheat. IPGRI Regional Office for Asia, the Pacific and Oceania, Serdang, Malaysia.


Appendices
Appendix 1: Programme of the 3rd BAPNET Steering Committee meeting

Monday, 22 November  
Arrival of participants

Tuesday, 23 November

8:00 am  Registration
8:30  Opening ceremonies
       Introduction of participants  Dr Cao Jun Ming
       Introduction of conference hosts
       Welcome remarks  Prof Luo Fuhe
                          President, GDAAS
       Messages
                          Mr Ma Xian Min
                          Vice Director, Guangdong Science and technology Bureau
                          Dr Zhang Zhongwen
                          IPGRI-East Asia Coordinator
                          Dr. Nicolas Roux
                          Musa Genomics and Genetic Resources Coordinator,
                          INIBAP Hq
                          Dr Agustin B. Molina
                          Regional Coordinator
                          INIBAP-Asia Pacific

10:00  Coffee/Tea break
10:30  Country presentations
       Australia  Mr Bob Williams
       Bangladesh  Dr Md. Abdus Satter
       Cambodia  Dr Men Sarom
       China  Mr Xu Linbing

12:00 nn  Lunch break
1:30 pm  paper distributed only
       India
       Indonesia  Dr Suyamto
       Malaysia  Dr Nik Masdek Hassan
       Myanmar  Dr Aye Tun
       Papua New Guinea  Ms Rosa Kambouou

3:10  Philippines  Dr Patricio S. Faylon
3:40  Sri Lanka  Dr C. Kudagamage
4:00  Thailand  Mr S. Chandraramnik
4:40  Vietnam  Dr Ho Huu Nhi
5:00  Secretariat of the Pacific Community  Dr Mary Taylor

7:00 pm  Welcome cocktails/dinner w/ cultural show
hosted by GDAAS
Wednesday, 24 November

8:10 am  Taiwan Banana Research Institute  Dr Chi-Hon Chen
8:30  South China Agricultural University  Dr Chen Houbin
9:00  South China Botanical Garden  Dr Ge Xue Jun
9:20  Zhongshan University  Prof Huang Xuelin
9:40  Guangdong Academy of Agricultural Sciences  Prof Huang Bingzhi
10:00  Hainan  Dr Chen Yeyuan
10:20  Coffee/Tea break
10:40  INIBAP-AP  Dr Agustin Molina
11:00  INIBAP-AP  Dr Inge Van den Bergh
11:20  IPGRI-APO- East Asia  Dr Zhang Zongwen
11:40  INIBAP Hq  Dr Nicolas Roux
12:00 nn  Lunch break
1:30 pm  Workshop/discussions
7:00  Hospitality cocktails/dinner hosted by INIBAP

Thursday, 25 November

8:10 am  Continuation of workshop/discussions
10:00  Coffee/Tea break
10:20  Continuation of workshop/discussions
12:00 nn  Lunch break
1:30 pm  Continuation of workshop/discussions
3:30pm  Conclusion
Election of new chairman
Nomination of date and place of next BAPNET SC meeting

Friday, 26 November

8:30 am  Field trip

Saturday, 27 November  Departure of participants
# Appendix 2 : Directory of BAPNET Steering Committee members/ hosts/ resource persons/ secretariat

## BAPNET SC Members

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Position</th>
<th>Organization</th>
<th>Address</th>
<th>Telephone</th>
<th>Fax</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Mr Robert Williams</td>
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<td>Department of Primary Industry and Fisheries</td>
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<td>(61-7) 40641151</td>
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</tr>
<tr>
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<tr>
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<td></td>
<td></td>
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Vice Chairman of Guangdong Provincial Political  
Consultant Committee

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### Secretariat

<table>
<thead>
<tr>
<th>Organization</th>
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<tbody>
<tr>
<td>INIBAP-AP</td>
<td>Ms Versalynn N. Roa</td>
</tr>
</tbody>
</table>
| GDAAS        | Prof Tang Xiaolang  
               | Prof Sun Ling       
               | Mr Shu Zhao Su      
               | Mr Yang Hu          
               | Ms Han Dong Mei     
               | Dr Wei Yue Rong     |
Appendix 3 : Awards

INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN
ASIA PACIFIC NETWORK (INIBAP-AP)
and the
BANANA ASIA PACIFIC NETWORK (BAPNET)

Presents this

Plaque of Appreciation

to

Xu Linbing

For his leadership in promoting banana R&D in China.

For his dedicated efforts in coordinating banana R&D cooperative projects and global research programs in Guangdong province in particular and in China in general.

For his valuable efforts in spearheading the 3rd BAPNET Steering Committee meeting.

In acknowledgment of his active participation as representative of China in the BAPNET Steering Committee resulting in productive cooperation and in recognition of his efforts in joining other Chinese scientists in the establishment of a Chinese banana R&D network that would advance a unified banana R&D in China.

This Plaque of Appreciation is given this 26th day of November 2004 during the 3rd BAPNET Steering Committee meeting in Guangzhou, China.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP Asia-Pacific

RICHARD MARKHAM
Director
INIBAP

INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a center of FUTURE HARVEST
INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN
ASIA PACIFIC NETWORK (INIBAP-AP)
and the
BANANA ASIA PACIFIC NETWORK (BAPNET)

Presents this

Plaque of Appreciation

to the

Guangdong Academy of Agricultural Sciences

In recognition of its strong commitment in banana and plantain R&D and of its cooperation with INIBAP as well as the active participation of its scientists in conferences and training programs.

In grateful appreciation for hosting the 3rd BAPNET Steering Committee meeting on 23-26 November 2004.

In acknowledgment of its participation in the National Repository, Multiplication and Dissemination Program in the Asia Pacific region in an effort to evaluate and adopt banana varieties that may solve major banana production constraints in China such as Fusarium wilt (race 4) and virus diseases.

This Plaque of Appreciation is given this 23rd day of November 2004 during the 3rd BAPNET Steering Committee meeting in Guangzhou, China.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP Asia-Pacific

RICHARD MARKHAM
Director
INIBAP

INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a center of

FUTURE HARVEST
INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN

ASIA PACIFIC NETWORK (INIBAP-AP)

and the

BANANA ASIA PACIFIC NETWORK (BAPNET)

Presents this

Pisang Raja Award

to the

Dr. S. Sathiamoorthy

In recognition of his outstanding contribution to banana R&D in India and in the region in general. He has devoted his career to banana research including the collection, conservation and characterization of the diverse Musa germplasm in India that resulted to the establishment of the largest field Musa collection in Asia. He had initiated a systematic banana breeding and selection programme leading to the development of banana cultivars in India. His scientific contribution to banana R&D can be gleaned from his technical publications as he authored and co-authored 236 publications that included 4 books and 5 book chapters.

In sincere appreciation of his cooperation and active participation in INIBAP programs/activities such as the ‘National Training on Musa Germplasm Information System’, and the ‘Workshop on Compilation of Names and Synonyms of Banana and Plantains in India’ held in Trichy, India in May 2001; the PROMUSA Working Group meeting held in Trichy, India in June 2003; the ‘Eco-friendly Management of Banana Nematodes’ held in Trichy, India in March 2004; and a member and previous convenor of the PROMUSA Genetic Improvement Working Group.

For his dedicated efforts in coordinating national cooperative projects on the National Repository, Multiplication and Dissemination Program and the global research program of the International Musa Testing Programme in India.

In gratitude of his active role in promoting banana R&D in India through participation as member of the INIBAP Steering Committee representing India in 2000.

This Pisang Raja Award is given this 23rd day of November 2004 during the 3rd BAPNET Steering Committee meeting in Guangzhou, China.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP Asia-Pacific

XU LINBING
BAPNET Chair
2004-2005

RICHARD MARKHAM
Director
INIBAP

INIBAP is a programme of the International Plant Genetic Resources Institute (IPGRI), a center of
## Appendix 4: Acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ABGC</td>
<td>Australian Banana Growers Council</td>
</tr>
<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
</tr>
<tr>
<td>APO</td>
<td>Agricultural Productivity Organization</td>
</tr>
<tr>
<td>APVMA</td>
<td>Australian Pesticide and Veterinary Medicines Authority</td>
</tr>
<tr>
<td>ASEAN</td>
<td>Association of Southeast Asian Nations</td>
</tr>
<tr>
<td>BAPHIQ</td>
<td>Bureau of Animal and Plant Health Inspection and Quarantine</td>
</tr>
<tr>
<td>BAPNET</td>
<td>Banana Asia Pacific Network</td>
</tr>
<tr>
<td>BARI</td>
<td>Bangladesh Agricultural Research Institute</td>
</tr>
<tr>
<td>BAU</td>
<td>Bangladesh Agricultural University</td>
</tr>
<tr>
<td>BBD</td>
<td>bacterial blood disease</td>
</tr>
<tr>
<td>BBTV</td>
<td>Banana Bunchy Top Virus</td>
</tr>
<tr>
<td>BBrMV</td>
<td>Banana Bract Mosaic Virus</td>
</tr>
<tr>
<td>BC</td>
<td>banana community</td>
</tr>
<tr>
<td>BLS</td>
<td>black leaf streak</td>
</tr>
<tr>
<td>BPI-DNCRDC</td>
<td>Bureau of Plant Industry - Davao National Crop Research and Development Center, Philippines</td>
</tr>
<tr>
<td>BS</td>
<td>black sigatoka</td>
</tr>
<tr>
<td>BSMRAU</td>
<td>Bangladesh Sheikh Mujibur Rahman Agricultural University, Bangladesh</td>
</tr>
<tr>
<td>BSV</td>
<td>Banana Streak Virus</td>
</tr>
<tr>
<td>CAM-SSCDC</td>
<td>China Agriculture Ministry, South Sub-tropical Crop Development Center, China</td>
</tr>
<tr>
<td>CARDI</td>
<td>Cambodian Agricultural Research and Development Institute</td>
</tr>
<tr>
<td>CATAS</td>
<td>Chinese Academy of Tropical Agricultural Sciences</td>
</tr>
<tr>
<td>CCI</td>
<td>Cocoa Coconut Research Institute, PNG</td>
</tr>
<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>CIRAD</td>
<td>Centre de Cooperation Internationale en Recherche Agronomique Pour le Developpement, France</td>
</tr>
<tr>
<td>cm</td>
<td>centimeter</td>
</tr>
<tr>
<td>CMV</td>
<td>Cucumber Mosaic Virus</td>
</tr>
<tr>
<td>CRCTPP</td>
<td>Cooperative Research for Tropical Plant Protection, Australia</td>
</tr>
<tr>
<td>CRI</td>
<td>Coffee Research Institute, PNG</td>
</tr>
<tr>
<td>CvSU</td>
<td>Cavite State University, Philippines</td>
</tr>
<tr>
<td>DA-BAR</td>
<td>Department of Agriculture - Bureau of Agricultural Research, Philippines</td>
</tr>
<tr>
<td>DAE</td>
<td>Department of Agriculture Extension, Bangladesh</td>
</tr>
</tbody>
</table>
DAR  Department of Agriculture Research, Myanmar
DMMMSU  Don Mariano Marcos Memorial State University, Philippines
DNA  deoxyribonucleic acid
DOST  Department of Science and Technology, Philippines
ECS  embryogenic cell suspensions
ELISA  enzyme-linked immunosorbent assay
EMS  Environmental Management Systems
EPMG  Evaluation and Promotion of *Musa* Germplasm
FAO  Food and Agriculture Organization of the United Nations, Italy
Foc  *Fusarium oxysporum* f.sp. *cubense*
FFTC  Food and Fertilizer Technology Center, Taiwan
FHIA  Fundacion Hondureña de Investigacion Agricola, Honduras
FSM  Federated States of Micronesia
ft  foot/feet
GDAAS  Guangdong Academy of Agricultural Sciences
GC  Giant Cavendish
GCTCV  Giant Cavendish Tissue Culture Variant
GDP  gross domestic product
GIS  Geographic Information Systems
ha(s)  hectare(s)
HBA  Hainan Banana Association, China
HGB  heated green banana
HOAFS  Heads of Agriculture and Forestry
IAEA  International Atomic Energy Agency, Austria
ICAR  Indian Council of Agricultural Research
ICHORD  Indonesian Center for Horticultural Research and Development
IFRI  Indonesian Fruit Research Institute
IITA  International Institute for Tropical Agriculture, Uganda
IMTP  International *Musa* Testing Program
INIBAP  International Network for the Improvement of Banana and Plantain, Montpellier, France
IPB-UPLB  Institute of Plant Breeding, University of the Philippines Los Baños
IPGRI  International Plant Genetic Resources Institute, Macaresse, Italy
IPM  integrated pest management
IPR  Intellectual Property Rights
ISPSC  Ilocos Sur Polytechnic State College, Philippines
ITTO  International Tropical Timber Organization
ITC  INIBAP Transit Centre, Leuven, Belgium
kg  kilogram
K.U.Leuven  Katholieke Universiteit Leuven, Belgium
LOA letter of agreement
m meter
MARDI Malaysian Agricultural Research and Development Institute, Serdang, Malaysia
MGIS *Musa* Germplasm Information System
MinSCAT Mindoro State College of Agriculture and Technology, Philippines
mo(s) month(s)
MTA material transfer agreement
NAFC National Agriculture and Fishery Council, Philippines
NARI-DLP National Agricultural Research Institute - Dry Lowlands Programme, Papua New Guinea
NARS National Agricultural Research System
NAST National Academy of Science and Technology, Philippines
NBPGR National Bureau of Plant Genetic Resources, India
NGO non-government organization
NPK nitrogen phosphorus potassium
NRCB National Research Centre for Banana, India
NTU National Taiwan University
PCARRD Philippine Council for Agriculture, Forestry and Natural Resources Research and Development
PC plant crop
PCR polymerase chain reaction
PG Polygalacturonase
PGR plant genetic resources
PME pectin methyl esterase
PMN Planting Material Network, Solomon Islands
PNG Papua New Guinea
PROMUSA Global Programme for *Musa* Improvement
QSC Quirino State College, Philippines
QUT Queensland University of Technology, Australia
QBAN Quality Banana Approved Nursery
RAPD random amplified polymorphic DNA
RC Regional Coordinator
R&D research and development
RFLP Random fragment length polymorphism
RGC Regional Germplasm Centre, Fiji
RISBAP Regional Information System for Bananaa and Plantain - Asia and the Pacific
RNA ribonucleic acid
RT PCR reverse transcriptase polymerase chain reaction
sp/spp. species
R&D research and development
RDE research, development and extension
SC steering committee
SCAU South China Agricultural University
SCUs, state colleges and universities
SCV, settled cell volume
SERD-PCARRD, Socio-economic Research Division, PCARRD, Philippines
SLPC, Southern Luzon Polytechnic College, Philippines
SOFRI, Southern Fruit Research Institute, Vietnam
SPC, Secretariat of the Pacific Community, Fiji
SPS, sucrose phosphate synthase
S&T, science and technology
t, tonnes
TBRI, Taiwan Banana Research Institute
TCP, tissue-cultured plant
TIS, Temporary Immersion System
TNAU, Tamil Nadu Agricultural University, India
TOPD-PCARRD, Technology Outreach and Promotion Division, PCARRD, Philippines
UHGB, unheated green banana
UPLB, University of the Philippines, Los Baños
UPLB-CEM, UPLB, College of Economics and Management, Philippines
UQ, Queensland University
VASI, Vietnam Agricultural Science Institute
VCGs, vegetative and compatibility groups
VFI, Virlanie Foundation, Incorporated, Philippines
VFRDC, Vegetable and Fruit Research and Development Center, Myanmar
VLIR, Flemish Inter-University Council, Belgium
VVOB, Vlaamse Vereniging voor Ontwikkelingsaanwerking en Technische Bijstand, Belgium (or Flemish Association for Development Cooperation and Technical Assistance)
WTO, World Trade Organization
YAU, Yezin Agriculture University, Myanmar
YLS, youngest leaf spotted
YS, yellow sigatoka