Advancing banana and plantain R&D in Asia and the Pacific - Vol. 11

Proceedings of the 1st BAPNET Steering Committee meeting held in Los Baños, Laguna, Philippines, 7-10 October 2002

A.B. Molina, J.E. Eusebio, V.N. Roa, I. Van den Bergh and M.A.G. Maghuyop, 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 programme 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).

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Cover: (Clockwise) Bananas transported in jeepneys; Filipino banana backyard farmer with his family; Bananas transported in a carabao-driven cart; Popular bananas in the Philippines - Bungulan, Latundan, Saba, Lakatan and Senorita.


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Banana Asia Pacific Network (BAPNET) is grateful to all participants of the 1st BAPNET Steering Committee for their contribution to this proceedings.

BAPNET would like to thank:

- Its local partners in the Philippines, the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) of the Department of Science and Technology (DOST) and the Bureau of Agricultural Research (BAR) of the Department of Agriculture (DA), for having provided the staff support and local arrangements that ensured the meeting’s success under the able leadership of Dr Patricio S. Faylon, Executive Director, PCARRD, and Dr Eliseo Ponce, Director, BAR;
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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-AP will be glad to assist.
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Workshop Recommendations
Workshop recommendations

After the presentations of country reports by each member representatives, a workshop was conducted. This workshop provided the venue to exchange opinions and formulate specific regional programs and activities of BAPNET based on the needs and priorities of the national agricultural research systems of each member country.

It was emphasized that the role of BAPNET is to coordinate the network information sharing, arrange for identified training needs and coordinate technical advice from within the region. At the national level, the projects identified will complement with each member country proposed R&D plans and ongoing activities.

The priority research programs identified were as follows:

**Sustainable crop management systems**

- Integrated pest management
  - Conduct surveys and mapping of pests and diseases in Asia Pacific particularly on viruses and the various *Mycosphaerella* leaf spot diseases.
  - Develop IPM technologies for important diseases (fusarium wilt, sigatoka, viruses, moko).
  - Conduct basic research on selected pests (leaf roller, scab, bacterial wilt, fusarium wilt).
  - Identify natural defence mechanisms against pests and diseases.
  - Develop diagnostic tools for banana viruses.

- Integrated farming systems
  - Identify various banana cropping systems (i.e. annual cropping, intercropping, crop rotation).
  - Determine ways to improve cropping system.
  - Conduct trials under farmers’ field.

- Integrated nutrient and water management
  - Identify proper nutrient and water management systems and evaluate crop performance. This includes use of both organic and inorganic fertilizers.
  - Determine ways to improve current systems.
  - Conduct trials under farmers’ field.

**Genetic diversity management, development and utilization**

- Collection and conservation
  - Establish strategies for regional conservation/use
• Collect, survey and map wild species.
• Develop regional core collections.

- Characterization and evaluation
  • Identify useful germplasm for farmers’ use.
  • Screen for pest and disease resistance.
  • Evaluate for high yield.
  • Publish variety catalogues.

- Germplasm improvement
  • Develop new varieties with high yield, resistance to pests and diseases and tolerance to drought/waterlogging.
  • Conduct genetic transformation studies.

- Germplasm multiplication and exchange
  • Exchange, multiplication and dissemination of improved cultivars.
  • Strengthen disease indexing and quarantine capability.
  • Develop improved propagation techniques.
  • Formulate policies and guidelines on germplasm exchange.

**Supply chain management**

• Conduct regional inventory of banana products and uses to determine how products can be improved and identify possible markets.
• Conduct national survey on postharvest handling and technologies to determine improved practices.
• Conduct field trials employing improved technologies under farmers’ field.

**Human resources development**

• Organize training on MGIS/GIS.
• Study tour/Training on the different aspects of banana production.
• Conduct training on plant genetic resources management.
  – Diversity analysis
  – Conservation technologies
• Organize exchange visits of banana scientists.

**Information management and exchange**

• Strengthen production and information exchange through the Regional Information System for Banana and Plantain (RISBAP).
• Develop market information systems for bananas.
• Develop a database on banana.
  – Names and synonyms of banana in Asia and Pacific (with photos)
  – GIS on pests and diseases
  – Nutrient and water management
Extension

- Promote high-yielding banana varieties among smallholders.
- Disseminate postharvest technologies for banana.
- Disseminate technologies on processing of banana for various uses.
Opening Ceremonies
Welcome remarks

Patricio S. Faylon*

Our friends and colleagues from the Asia Pacific region, ladies and gentlemen, good morning.

On behalf of PCARRD and the entire Philippine National Agriculture and Resources Research and Development System (NARRDS), and as current Chair of the Banana Asia Pacific Network (BAPNET), it is a privilege for me to welcome all of you to the Philippines. I hope you all had a pleasant travel coming to this country, and may your stay here be both enjoyable and rewarding.

I am confident that our meeting today will be as memorable and productive as last year’s meeting, although I hope that this time, we will be able to come up with specific programs and activities, in consideration of the needs and priorities of all the partner NARS, on banana and plantain R&D.

At this point, allow me to extend to you the apologies of our Science Secretary Estrella F. Alabastro, for her inability to join us in today’s important gathering. While she had confirmed her attendance to this meeting, she had to beg off due to a very crucial matter she has to attend to, which is the budget deliberation called upon by our legislative body, aimed at rationalizing government investment to all its agencies/organizations. In fact, I was also required to attend the said budget deliberation, but I had to decline and justify the need for me to be here with you today, this being an equally important activity for us in the R&D sector.

I would like to inform you, though, that Secretary Alabastro has promised to join us all during the closing ceremonies – so that she will have a chance to meet all the participants of this meeting. In view of her absence, allow me then to read to you her welcome message.

*Executive Director, DOST-PCARRD, Los Baños, Laguna, Philippines.
Strengthening NARS partnership towards the advancement of the banana industry in the Asia Pacific region

Estrella F. Alabastro*

Distinguished participants, ladies and gentlemen, a pleasant good morning to all.

On behalf of the Philippine NARS, allow me to extend my warmest welcome to all the representatives of the different NARS of the Asia-Pacific Region to this 1st Banana Asia Pacific Network (BAPNET) Steering Committee Meeting. The whole Department of Science and Technology (DOST) family feels deeply honoured to host this very significant regional event, and to be one with BAPNET in advancing your vision to make banana and plantain R&D benefit the region’s poor.

We likewise extend our sincere appreciation to the Department of Agriculture-Bureau of Agricultural Research (DA-BAR) for co-hosting this meeting, and to the International Network for the Improvement of Banana and Plantain (INIBAP) for organizing this important gathering.

In many parts of the Asia Pacific Region, populations continue to rise, coupled with growing rates of resource extraction, uneven distribution of resources and inability to access available food. Attaining food security and addressing widespread poverty are not mainly demographic issues. For the most part, agricultural and natural resources R&D is a crucial requirement to attend to the needs of a gradually expanding number of people, as well as, the increasing level of standard of living in the region.

The multi-faceted and interconnected nature of regional development issues, such as food security, loss of biodiversity, widespread poverty, and unsustainable extraction of resources, necessitates consolidation of efforts at the regional level of agricultural systems. Experiences in the past point to the weaknesses of independent and fragmented national R&D systems working on challenges of agricultural productivity and sustainability. Many NARS had to contend with resource limitations to address R&D needs; yet, some of these concerns

*Secretary, DOST, Bicutan, Taguig, Metro Manila, Philippines.
have already been attended to by the more advanced NARS.

Within the context of regional partnership and collaboration, vast opportunities are open to the NARS. The formation of commodity-based regional networks now better harmonize R&D activities in the region. Where there is so much to be done and very little resource to do with, the need for NARS partnership becomes vital toward bringing the best of advanced research to each partner country.

Our commitment to host this 1st BAPNET Steering Committee meeting is very well fitting in the context of regional partnership towards the enhanced exchange of science-based knowledge, which has now become the yardstick of progress and development. Commodity-based networks now have a more crucial role in advancing technological interventions in agricultural production and distribution. From simply providing for demands of our respective local market, our agricultural R&D goals have broadened to include meeting the standards of globalization. Harnessing regional partnership such as the BAPNET has now become vital, particularly among us countries of the Asia-Pacific Region, where we have ecological correlations and common R&D concerns.

Primarily because of our geographical advantages, countries in Asia and the Pacific have the competitive advantage of producing bananas for local and export markets. This edge has encouraged most countries in the region to strengthen their respective national banana R&D programmes. Through the continuous conception of knowledge, germplasm and technologies made available by INIBAP, banana R&D in the region is continuously enhanced.

Particularly in the Philippines, banana dominates the tropical fruit industry in terms of hectarage and production. It occupies more than half of the total area planted to different tropical fruits. The banana industry contributes more than $200 million annually, ranking 2\textsuperscript{nd} among the top Philippine agricultural exports for the past two years. As part of our commitment to the upliftment of the region’s banana industry, our country has been the host of the Asia-Pacific germplasm collection based in Davao in the southern Philippines.

Realizing the present benefits and great potentials of the banana industry, R&D efforts for its improvement is very evident in our national programs. Banana is considered one of the priority horticultural crops under the Small Enterprise Technology Upgrading Program (SET-UP) of the DOST, the High Value Commercial Crops Programs (HVCC) of the DA-BAR, and the Investment Priority Plant of the Board of
Investments-Department of Trade and Industry (BOI-DTI). Moreover, under the DOST-PCARRD Medium Term Plan, biotechnology researches on the development of disease-resistant banana varieties are now making headways. Aside from improved varieties, our efforts are also being directed towards postharvest technologies to improve the quality of banana products for the world market.

Our respective national programmes on banana address common needs and interests. In these trying times, most if not all of the NARS in the region are faced with limited R&D resources. Thus, in the process of uplifting our banana industries, complementation of activities toward a unified effort is the challenge that the BAPNET has to surmount. On this note, we pledge our full support to BAPNET and to the member-countries of this network in coming up with focused programmes and initiatives to realize the full potentials of the region’s banana industry.

We are hopeful that this activity becomes the venue to critically plan the specific programmes and the direction that the banana and plantain industry of the Asia-Pacific Region will pursue in the coming years. Your participation to this very first Steering Committee Meeting of BAPNET is vital in terms of laying the foundation for a coordinated R&D approach toward the sustainable development of banana and plantain in the region.

BAPNET, as a collaborative undertaking, must be anchored on a coherent R&D strategy based on the needs and priorities of the different NARS. We are confident that with the expertise of the representatives from the participating NARS present here today, we can achieve the objective of setting the groundwork for a coordinated R&D approach.

We strongly appreciate your active commitment and dedication to the vision of BAPNET. We hope that our long journey together to achieve this vision will be a fruitful and productive one, for the benefit of the millions of marginalized banana farmers in Asia and the Pacific.

Again, welcome to the Philippines, and Mabuhay!
Message

Nicomedes Eleazar*

Distinguished guests, ladies and gentlemen. a pleasant day to all of you. In behalf of Secretary Leonardo Montemayor of the Department of Agriculture, it is my pleasure, to welcome you in this important event in the banana industry. It is the Philippine’s pride and honour to host this first ever, Banana Asia Pacific Network Meeting.

From, its wild origins in Asia and the Pacific, banana has spread throughout the tropical world – Africa, South and Central America and the Caribbean. As food and important source of income, banana has been elevated to a new level of importance in global trade and commerce from its humble beginning in the Pacific. In the Philippines, it is a fact that banana is one of the top high value commercial crops.

But the industry’s road to greatness is surrounded by challenges. The onset of the destructive fungal disease, black sigatoka during the 1980s started the global level cooperation in controlling the concerns that plagued the banana industry. The creation of INIBAP served as the germination period for international cooperation for the upliftment of the industry.

This meeting is a good venue for sharing experiences, data and information on banana and plantain and in the conduct of collaborative programs and projects in the spirit of regional cooperation in agricultural research and development particularly on this high value crops. Through our collective effort, it is hoped that we will continue to face the challenges ahead.

In this era of globalization, creation of partnership and support in areas of research and production, is timely and shall ensure our success in response to the aforementioned challenges.

Again, in behalf of the organizers of this meeting, I welcome you all in this momentous event and I wish you a productive and fruitful results. Thank you and good day to all.

*Assistant Director, DA-BAR, Diliman, Quezon City, Philippines.
Message

Agustin B. Molina*

On behalf of the Director of INIBAP, Dr Emile Frison, I would like to welcome you to the first Steering Committee meeting of the relaunched BAPNET. Emile wanted to attend this important meeting but he has other prior equally important commitments. He has always been following up the developments of our Banana Asia Pacific Network. He asked me to convey his best wishes to all and that we will have a productive and successful meeting.

I would like to express our sincere thanks to the Philippine NARS, PCARRD and BAR. I really appreciate the presence of Dr Patricio S Faylon for locally hosting and organising the first planning meeting of the relaunched BAPNET. Dr Faylon is supposed to defend the PCARRD budget but because of the importance of this meeting, he delegated this responsibility to his deputy. Thank you, Pat. And of course, I also appreciate the BAR for co-hosting this important occasion.

The relaunching of the BAPNET is the culmination of the successful existence of the Asia and Pacific network (ASPNET). INIBAP has initiated the creation of ASPNET in 1991 as a regional network to enhance regional collaboration in banana R&D. Its 10 years of existence have resulted in productive collaboration, particularly in the area of germplasm management, that is in collection, conservation, characterization and evaluation. INIBAP through ASPNET also had supported activities in the area of information development and exchange, and human resource development through trainings, seminars and workshops. Thanks to the participation of the NARS, because INIBAP works with the NARS, and to my predecessor, Dr Ramon Valmayor and the previous Regional Advisory Committee members. Some are still here in the presence of Dr Hwang, Bob Williams, Tom Osborn. After 10 years, we have to go to the next level.

However, through the years, ASPNET was viewed as an INIBAP network; well for good reasons being a creation of INIBAP, and most of its activities are INIBAP-initiated activities. INIBAP has several programmes that can help the region to advance Musa R&D and we have done so. But we have to go to the next level of challenges – to

*Regional Coordinator, INIBAP - Asia Pacific, c/o IRRI, Los Baños, Laguna, Philippines.
have a network that is strongly NARS-based, initiated by the NARS. Programs and activities are priorities of the region and planned by the NARS. That is the reason why we came to attend the workshop last year in Sri Lanka and that was the creation of BAPNET. And this is the first Steering Committee meeting. Even the name of the committee has changed. It used to be Regional Advisory Committee; it connotes that it is only advising, now it is the Steering Committee. It means that it will steer the future activities of the network. So we have to identify the priorities and create programs. And INIBAP will continue as the secretariat to put people together to enhance this collaboration. And I hope that in this first Steering Committee meeting, we will be able to come up with actual activities and projects of the network. And again, INIBAP will always be behind to enhance this regional initiative. INIBAP also has its own global programmes that I hope can also enhance the activities of the network. Again, I appreciate very much your presence and I hope that in the next 2-3 days we will have a very productive meeting and we come up with good programmes that would uplift the banana industry in our region.

Thank you.
Country Reports
Banana industry status and R&D update in Australia

Robert Williams*

General production issues

Banana production in Australia over the past 18 months has been through a period of very difficult times. In north Queensland, the major production area for Cavendish, an outbreak of black sigatoka occurred in April 2001. This is the first occurrence of black sigatoka in the production area. An intense controlled management program of zero disease tolerance was implemented, and no detections have been made since August 2001. A detailed report on the outbreak and process and progress is presented in Annex 1.

In Northern Territory, no further outbreaks of Fusarium oxysporum f.sp. cubense (Foc) tropical race 4 have been detected, although there are now only two major growers in the area. The fusarium-testing site is operating very well in screening cultivars for tolerance.

Drought conditions in the southern production areas of Queensland and northern New South Wales, together with the presence of Banana Bunchy Top Virus and Foc race 1 and 4 is restricting the expansion of Lady Finger in this area.

Current Australian production is just over 22 million cartons (297 000 tonnes) for approximately 14 000 hectares. Consumption has continued to increase to just over 15 kilograms/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. Small quantities of ABB Ducasse (Pisang Awak) and AAAB Goldfinger are providing a demand in niche markets. Some potential exists for the development of specialist markets for organically grown or eco-labelled bananas together with new varieties for both dessert and cooking types.

The major cultivars grown are: Cavendish (90%), Lady Finger (7%), Goldfinger (2%) and other varieties (1%).

*Programme Leader, Tropical Tree Fruits, Queensland Horticulture Institute, Agency for Food and Fibre, South Johnstone, Queensland, Australia.
Restraints on the industry

Similar to all other banana producing countries, the Australian industry is very labour intensive. However, the cost of labour in Australia is very high compared to other countries, so our production systems are significantly different in an endeavour to reduce labour cost. Compounding this labour issue, the government, consumers and the community have expectations on the way the industry conducts its business by imposing regulations such as workplace health and safety, environmental protection, freshcare and intra and interstate quarantines.

Research programs

Outcomes and progress in the research and development projects have been significant. Abstracts of many of the projects are attached in Annex 2.

The R&D program is focusing along four major themes:

Competitive production systems

- IPM: Developing a systems approach to pest and disease control;
- Decision support: Production and management systems that maximise efficiency;
- Irrigation/Nutritional management to maximise inputs but minimise environmental impacts;
- Diagnostic tools for pest and disease detection;
- Mechanisation of production and packaging systems.

Environmental sustainability

- Soil health: Developing monitoring tools as indicators of environmental impact;
- Environmental management systems combining the various productions and management.

Product innovation

- Breeding/Selection
- Marker technology
- Food solutions
Supply chain solutions

- Market access disinfection
- Postharvest handling
- Quality assurance systems
- Identifying customer needs

Banana research agencies in Australia

- Queensland Horticulture Institute (QHI)
- Queensland Agricultural Biotechnology Centre (QABC)
- 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

Peak industry body

Australian Banana Growers Council (ABGC)

Collaboration prospects

Australia has over many years collaborated extensively with many Asia-Pacific countries in a wide range of research projects. This collaboration has resulted in Australia having an extensive strong team in:

- *Fusarium*
- Viruses of banana
- Nematodes of banana
- *Erwinia*
- *Mycosphaerella* spp (sigatoka diseases)
- Integrated pest management
- Banana tissue culture
• Banana characterisation
• 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.
Annex 1

Black sigatoka eradication programme in Australia
Tully banana production area (TBPA)

Background

Previous findings of black sigatoka
Since 1981, black sigatoka (BS) has been found on eight previous occasions in the Cape York area. Level of infection at each finding ranged from a few plants (Upper and Lower Pascoe River, Upper Daintree, Bloomfield) to throughout townships (Bamaga and surrounding communities, Weipa) to a commercial plantation (Daintree).

At each finding, the following procedure was followed:
  − Identification confirmed;
  − Survey to determine extent of disease;
  − Assessment of action required; depended on location of outbreak, extent of disease, etc;
  − Eradication of all diseased plants plus plants in a buffer area;
  − Replacement of diseased plants with resistant plants;
  − Follow-up surveys, one to two per year.

All findings were successfully eradicated and except for Bamaga, no re-occurrences of BS have been detected in the regular intensive surveys of all locations. Bamaga was the area where BS was first found in 1981 and early eradication programs were not as intense or detailed as subsequent programs.

All areas where BS was found were linked, mainly through the Alternate Lifestyle Communities/Groups. These groups are gardeners and collectors of plants. Planting material for the communities is collected from a wide range of sources.

Tully finding

BS was confirmed on a sample from near Tully on 3 April 2001.

Surveys

  • Extensive surveys in the April-June period defined the outbreak to the Tully area.
• In the 12-week period, 2773 samples of diseased leaf tissue were sent to the laboratory for identification.

• Sixteen were positive for BS (*Mycosphaerella fijiensis*); 11 samples were from commercial farms and 5 from unmanaged plants (feral, residents, regrowth areas).

• Of the samples, 2432 were positive for yellow sigatoka (YS) (*Mycosphaerella musicola*).

• Other diseases were identified in 1835 samples.

**Biology of *Mycosphaerella fijiensis***

An eradication program was devised based on the biology and survival characteristics of the fungus.

*Mycosphaerella fijiensis* can only invade bananas (*Musa* spp.). There are no alternate hosts, neither symptomatic nor asymptomatic. *Mycosphaerella fijiensis* does not produce specialised survival/dormant structures. It produces three spore types: conidia, ascospores and spermatia.

• **Conidia** – produced on the surface of stage 4 and early stage 5 leaf lesions, are readily dislodged by water and can be dispersed in water droplets to leaves, but most are washed onto the soil. No evidence of conidia being re-dispersed from soil to leaf tissue and resulting in a disease.

• **Ascospores** – produced in structures (perithecia) inside leaf tissue. Mature ascospores are forcibly ejected from the perithecia into the air when the surrounding tissue, including cells of the perithecia, absorbs moisture.
  
  o Ascospores are ejected following rain (>1 mm), irrigation, but dews rarely result in the release of ascospores.

  o Perithecia continue to produce and eject ascospores while the leaf tissue remains intact. Perithecia are known to continue to eject ascospores for more than 5 months where the leaves hang in the canopy but for only 1-2 months when the leaves are placed on the ground and decompose.

• **Spermatia** – are involved in the spermatisation (fertilisation) of the proto-perithecia resulting in the production of ascospores. Spermatia require a film of water over the leaf surface to be dispersed from the spermogonia to the proto-perithecia. The optimum temperature for *M. fijiensis* is 27–28 °C and little growth including ascospore production occurs below about 20 °C or above 34 °C. The optimum temperature for *M. musicola* is 1-2 degrees lower with few ascospores produced below 18 °C.

In north Queensland, preliminary data suggest that during most seasons, production of perithecia/ascospores by *M. musicola* is extensive during the wet season, but is very limited during the periods June to August, due to cool
conditions and August to October/November due to dry conditions. Ascospores released/ejected in the spring/early summer period have been carried over the winter and spring periods in the perithecia produced during the late autumn (April-May) period.

Removal/deleafing of necrotic disease lesions in the winter/spring period substantially reduces inoculum production in spring and early summer periods. Deleafing reduces potential ascospore release by >80%.

Normal weather pattern in the TBPA is for the period July to August to be cold (night temperatures well below 20 °C) and for the period August to October to be dry.

**Eradication program**

The program was devised in May/June 2001, to eradicate *M. fijiensis* from the Tully area based on:

- Surveys indicated *M. fijiensis* was restricted to the Tully valley area.
- Survey data suggested the outbreak was relatively recent (16 positive BS samples from 2773 examined, few with mature lesions)
- Program was based on deleafing/removal of all diseased tissue from the plants in the TBPA, an intense spray program to prevent new infections and the destruction of all unmanaged plants in the area.
- Under an inspectors’ approval, the following regulations were introduced:
  - All properties had to achieve and maintain a zero visible disease level
  - Where an inspector detected disease, a Direction Section 11 was issued which prevented the movement of fruit until all visible disease was removed.
  - The program was divided into four stages:
    * Stage 1: April to June 2001 - surveillance;
    * Stage 2: July to November 2001 - zero disease
    * Stage 3: December 2001 to June 2002 - monitoring for zero disease
    * Stage 4: July 2002 to June 2003 - disease monitoring - area freedom;
      [Growers responsible for disease control programmes from June 2002].
- For market access into New South Wales and regulatory issues (disease levels) in relation to the outbreak and proposed BS eradication program, all banana plants in the TBPA were deemed to be diseased with BS.
- The TBPA was defined as the area extending from latitude 18.172 near
Dallachy Creek in the south to latitude 17.773 near Kurrimine Beach in the north and west to the range. These boundaries established on natural breaks in areas planted to bananas and were >20 km from known infected sites.

- The TBPA included nearly 4400 ha of commercial bananas on 162 properties (137 growers).

- Eradication program consisted of three components:

  Zero visible disease
  
  - All leaves with any visible sigatoka lesions were removed from all commercial banana plants throughout the TBPA and placed on the ground.
  
  - Deleafed leaves placed on top of previously deleafed leaves to reduce ascospore release.
  
  - All plants deleafed of all diseased tissue at 2-4 week intervals.
  
  - All plants free of lesions within 2 months (August) of the program commencing and all trash containing lesions were placed on the ground for 3-4 months (December) before the wet season.
  
  - All bananas monitored for disease at 4-6 week intervals by trained monitors.
  
  - Samples of all leaf spot detected submitted to the QHI Plant Pathology Laboratory at the Centre for Tropical Agriculture in Mareeba for identification.

Spray program

- An intense spray program applied to prevent the establishment of new infections from ascospores released before the trash has decomposed.

- Spray program included both protectant and systemic fungicides.

- Petroleum oil included with all fungicides.

- Systemic fungicides applied as per Fungicide Resistance Action Committee (FRAC) recommendation for bananas to reduce the risk of resistance.

- Systemic fungicides rotated.

- Sprays applied weekly with the protectant fungicides applied between all applications of the systemic fungicides.

- Spray program coordinated to ensure all areas were sprayed and all areas received the same fungicides.

- A special spray program devised for Organic Growers.
Eradication of unmanaged plants

- Unmanaged plants to include feral plants, residential plants and regrowth plants.
- All feral bananas (on roads, creeks, rivers, etc.) located and destroyed.
- All residential (urban and rural) blocks visited and all unmanaged bananas destroyed.
- All residents who wished to keep their bananas required to keep the plants free of leaf disease (spray and deleaf).
- All regrowth banana plants in old banana blocks/abandoned banana areas destroyed.
- Samples of all leaf diseases detected submitted to the laboratory for identification.

Surveillance for black sigatoka outside TBPA

- Surveillance of banana areas surrounding the TBPA was undertaken to determine if BS was restricted to the TBPA.

- All properties in the Innisfail and Kennedy Banana Production Areas (within 50 km of the TBPA) visited and sampled for leaf spot. A piece of leaf with stage 4/5 lesions collected at 100 m intervals in every 4-5th row (a sample = 15-20 pieces of leaf/10 ha).

- The buffer area, Kurrimine line to the South Johnstone River, sampled at the rate of a sample/5 ha.

- All samples of disease submitted to the laboratory for identification.

Summary of results to date

- Data as of May 2002 strongly suggest that the eradication program was successful.

- Conditions, suitable for infection, occurred on a number of occasions from January to April with extended periods in late January (rain on 7 consecutive days), February (13 days), early April (16 days) and late April - early May (13 days).

- BS only at 25 sites – 13 managed plantations and 12 unmanaged banana sites (9134 samples examined, 3114 by PCR)

  - No BS detected on commercial plantations since 13 August 2001 (>9 months and 4115 samples examined since 13 August).

  - No YS detected in 56% of plantations/46% of banana areas in TBPA in round 4, with another 36%/44% at extremely low levels (<15 pieces of
leaf/plantation 1-342 ha). In round 5, >96% of plantations and area were at zero or at extremely low levels of disease.

- All disease lesions found in the plantations with extremely low levels of sigatoka were examined and all were YS demonstrating that the vast majority of bananas in the TBPA are free of BS.

- Samples from the other 3-4% of bananas were also examined and all were again YS. All remaining disease on these plantations was deleafed to zero within 2 days (no Directives were issued in 5).

- No BS detected on unmanaged plants since 16 November 2001 (>6 months and 478 samples examined).

- All land parcels in TBPA (7629) were visited from January to March and all unmanaged bananas located were examined for disease and all disease was identified. No BS was found in 474 samples collected and examined from unmanaged banana plants.

- *Mycosphaerella fijiensis* cannot survive outside a banana leaf for more than a few days and no more than 5-6 months inside leaf tissue on the plant and <3 months in tissue on the ground.
Annex 2

Banana research programmes in Australia

Introduction

This document summarises most of the RD&E projects currently being conducted within Australia.

Presented for each project is an overview of the project objectives and summary of the progress to date.

Project title: Plant protection extension in the Queensland banana industry

Project duration: 1 July 1999 - 30 June 2002

Continued productivity and maintenance of fruit quality are major issues for banana producers in Queensland. Appropriate management of pests and diseases is a major factor in meeting the market requirements for quality and the productivity requirements for profitability. This project aims to facilitate the development of better pest and disease management practices by Queensland banana growers by providing better communication and information transfer. This can be achieved with the following activities:

* Continued production and distribution of 'Bananatopics' newsletter for growers;
* Assistance for the production of the annual grower publication, 'Banana Protection';
* An industry awareness program for exotic and endemic quarantine threats;
* Industry activities aimed at extending the results of pest and disease research;
* Industry extension of regulatory requirements for growers.

Production of the newsletter, 'Bananatopics', and industry extension for pest and disease management have been identified as high priorities by the Banana Sectional Group Committee of the QFVG.

This project aims to continue industry extension work started by the project FR96022. This proposal will also link with the existing and proposed research projects on banana pests and diseases affecting quality and productivity:

* Erwinia corm rot
* Burrowing nematode control
* Banana streak virus
* Banana rust thrips
* Yellow sigatoka (YS) resistance monitoring.

Summary of milestones

Integrated nematode management

- Significant progress has been made in the development and implementation of IPM practices for burrowing nematode, especially the use of non-host

- The use of ‘Callide’ Rhodes grass in fallows has presented the opportunity for commercial seed harvesting, and a seminar was held with a commercial seed merchant for interested growers on the seed industry and its requirements. This has led to technical staff from the seed merchant assisting growers in the Tully and Innisfail district with production advice. Seed harvesting is beginning in June 2002.

- Training workshops on IPM for burrowing nematode are being conducted in the NQ production regions. From this workshop, publications are being prepared for ‘Bananatopics’ and ‘Australian Bananas’.

**IPM for banana bunch pests**

- The project officer’s involvement with Crop Care Australia and IBS in Innisfail have resulted in the development of a mechanical application device for the SusCon® ribbon. Consequently, Crop Care has proceeded with registration of the product, and it is expected to be available to producers by July 2002. The project officer has been involved in field demonstrations for producers with Crop Care.

- Results from research trials on biopesticides and ‘new chemistry’ insecticides for bunch pest management have been published in ‘Bananatopics’.

**Leaf disease management**

- The project officer was involved in presenting information at 12 regional YS management workshops in April and May in NQ production area.

- The project officer works with chemical companies and regional local agribusiness outlets to update banana fungicide resistance strategy to include new strobilurin fungicides.

**Next steps**

- Continue industry-wide extension training in integrated nematode management as required for Queensland production regions. Articles for industry publications are being published from this work.

- Continue to monitor performance of fallow crop trial sites to determine period between replanting and nematode population reaching damaging levels.

- Actively collaborate with project leader FR99011 to update and produce grower manual on integrated management of burrowing nematode.

- Assist in the communication and extension of results from research project on IPM for bunch pests.

- Continue to conduct grower and agribusiness discussion groups in NQ production region. It is intended to use these groups to help evaluate project actions and outcomes.

**Communication/Extension activities**

- The full colour banana quarantine threats information sheets have been posted to all registered banana producers in Queensland to complement previous activities in Tully and Innisfail.
A seminar on commercial seed production from fallows of ‘Callide’ Rhodes grass was held for producers in Tully in February 2002. The prospect of a financial return from fallows has raised enormous interest in the use of fallows for management of burrowing nematodes.

The project officer has actively participated in 12 leaf disease management workshops for producers in NQ in April and May.

The project officer has actively participated in 4 field days for producers in NQ demonstrating the new SusCon® ribbon for bunch pest management.

The BAGmen group (agribusiness discussion group) has agreed to review the banana fungicide resistance strategy to include the new strobilurin fungicides.

A weekly radio spot is used to inform growers of pest and disease information and activities in the local region.

**Project title:** Integrated systems for managing nematodes on bananas

**Project duration:** 1 January 2000 - 31 December 2002

**Synopsis of project**

Burrowing nematode is the most important nematode on bananas in Australia and worldwide. This project investigated several options of improving nematicide application including the strategic application of soil-applied nematicides, the efficacy of application of nematicides in the sub-tropics and the efficacy of pseudostem injection of systemic nematicides. With the discovery of natural suppression of burrowing nematode in some Australian banana crops, nematode antagonistic organisms are to be isolated and screened to suppress burrowing nematode. The resistance of banana cultivars to Pratylenchus goodeyi and Radopholus similis will be determined. Alternate methods to disinfest planting material to eliminate R. similis are to be investigated. Extension material will be updated and workshops will ensure results are disseminated to the industry.

**Progress to date**

The project is currently being finalised and extension material and the final project report are being prepared. The progress in the project work areas is listed below.

**Nematicide application**

- Strategic nematicide application was determined to be the best method of applying nematicides to the soil. When the currently registered nematicides for bananas, Nemacur®, Rugby®, Counter® and Vydate®, were applied in rotation, there was significantly less damage caused by burrowing nematode to the roots of banana plants and reduced numbers of nematodes, relative to both the untreated plants and plants where the nematicides were applied consecutively every 3 months. The development of enhanced biodegradation was also delayed when nematicides were rotated. The time of year when the nematicides were applied was not as important as the rotation of the
chemicals. There appears to be no cross degradation between nematicide products, although this is still currently under investigation.

- Efficacy of nematicides in sub-tropical bananas was not as good as in the tropics. In the sub-tropics, negative economic returns resulted from nematicide application. Two different management regimes were used in the trial: poor management practices increased the impact of nematodes on plants and also reduced the efficacy of the nematicides. The investigation of enhanced biodegradation with continual use of nematicides is being finalised.

- Pseudostem injection trials were performed with registered nematicides Nemacur® and Vydate® as well as some new developing products. The injection of Vydate® into the pseudostem was found to be as efficacious as soil application. There was evidence which suggested that Nemacur® also reduced the number of nematodes in the roots of bananas when injected into the following pseudostem of bananas. Nemacur®, however, was more phytotoxic than Vydate®. The efficacy of the unregistered chemicals was poor. Some products warrant further investigation.

**Biological control**

Organisms with potential as biological control agents were isolated from the rhizosphere and within the roots of banana plants. A non-pathogenic isolate of *Fusarium* recovered from a farm in the sub-tropics significantly reduced the number of nematodes in the roots system of banana plants as well as stimulating the growth of the plant. In the tropics rhizobacteria isolate (fluorescent *Pseudomonas* spp.) were also able to increase plant growth and reduce the number of nematodes on the roots. Bacteria beneficial to banana growth and nematode suppression were found in composted material. The use of compost may increase the natural suppression of bananas and increase the robustness of tissue culture plants.

**Cultivar resistance**

Cultivar resistance to burrowing nematode was tested on tissue culture plants as well as bits. The cultivars had a variety of genomic mix. Yangambi Km5 was found to be the most resistant banana cultivar in all trials. FHIA-03 was also found to be resistant relative to Williams.

**Alternative planting material**

Alternative planting material disinfestation methods to Nemacur® were not successful in eliminating burrowing nematode from the corm material. Alternative methods that were trialed included hot water, bleach and Vydate®. Nemacur was not 100% effective in eliminating nematodes from planting material.

**Extension**

Extension material is currently being prepared to include the results of this project. Workshops and field days have been conducted during the progress of the project to update banana growers on changes in management methods.
Project title: Enhancing market penetration of Lady Finger bananas

Project Duration: 30 December 1999 - 30 June 2003

Summary

We will improve the quality and consistency of Lady Finger bananas grown and marketed in Australia by:

- Assisting Lady Finger growers to develop and implement improved marketing practices;
- Assisting Lady Finger growers to develop and implement ‘best practice’ for Lady Finger production.

This is a joint project between QFVG, QDPI, NSW Department of Agriculture and BIC, and Australian growers.

The Lady Finger industry has a well-established niche market (approximately 5.1% of Australian banana production), valued at $16.85 million. Ladyfinger bananas are grown in many areas of Australia, from the Atherton Tableland (Mareeba) and the Wet Tropics (Tully) in North Queensland to Coff’s Harbour in New South Wales. A grower preference for Lady Finger bananas, especially in many cooler and drier parts of Australia, combined with an identified segment of consumer preference for acid-sweet bananas, justifies the promotion of a separate but complementary niche market for this product. This project is aimed at all Lady Finger growers in Queensland, including those in the Wet Tropics and the Atherton Tableland.

The Lady Finger industry has many serious problems, such as:
- Lack of official quality standards for Lady Finger fruit (although there are size standards);
- Widespread quality problems in the industry, due to a poor understanding of best practices in growing and handling Lady Finger;
- An absence of organised Lady Finger marketing groups;
- No Lady Finger quality assurance systems, which have third party accreditation;
- Extremely serious problems with Fusarium oxysporum f.sp. cubense (Foc) race 1 and 4 (and possibly tropical race 4 in the future);
- High susceptibility to yellow sigatoka and speckle;
- Bunch pest problems.

This project addresses the following issues identified as priorities by the ABGC research and development priority plan in March 1998:

1. Quality systems Priority 1
2. Professional marketing systems Priority 1

Progress to date

- Market throughput analyses completed
• Price/Quality analyses in markets completed
• Consumer survey completed
• Retailer survey completed
• Australian size grade standards for Lady Finger bananas developed
• Product description language for Lady Finger fruit developed
• Guidelines for Lady Finger carton packing developed
• Maturity and harvesting procedures for Lady Finger bananas developed
• Newsletters sent to all Queensland Lady Finger growers
• Subtropical Agrilink kit draft completed
• Sustainable best practices growing guide developed for Lady Finger growers by NSW Agriculture in conjunction with QDPI
• Coff's Harbour forum addressed on results of Lady Finger project to date

Project title: Diagnosis of banana pathogens

Project Duration: 1 July 1999 - 30 June 2002

Synopsis

The Australian banana industry is constantly challenged by pests and diseases from overseas and by pests and diseases already established in Australia. The industry has developed an Approved Planting Material Scheme, which requires regular detection and identification of banana plant pathogens. Proposed new planting material regulations will greatly increase the number of samples required to be processed. Faster and more reliable detection and identification methods being developed in this project will help ensure the success of the planting material scheme and reduce its cost and prevent further losses to the industry from established and exotic pests and diseases.

Banana Streak Virus (BSV) is widely distributed in Australia, and has been found in all commercially important cultivars. BSV is highly variable and all isolates characterised are different. Research done overseas suggests that all banana cultivars have BSV sequences integrated into the banana genomic DNA. In some cultivars, it is thought that this integrated DNA may be activated by stresses such as tissue culture and artificial breeding, giving rise to new virus infections. This project will characterise the extent of variation of BSV in Australia and assess whether they differ in biological properties such as host range and reaction on bananas. The easiest approach to investigating biological properties will be to produce infectious DNA clones, which will be used to inoculate plants by biolistics. BSV sequences that are integrated into the genomes of commercially important cultivars will be characterised and compared with those obtained from field infections in a range of cultivars.

All four races (1, 2, 3 & 4) of Fusarium oxysporum f.sp. cubense (Foc) are present in Australia. Races can be identified using vegetative compatibility group (VCG) analysis. However, VCG analysis is expensive and time-consuming. Polymerase Chain Reaction (PCR) is an extremely rapid, accurate and sensitive method for the identification of fungi and should be capable of identifying Foc in...
infected host tissue as well as in pure culture. It will also identify genetic variability within a VCG. DNA fingerprint analysis of Australian isolates has already identified seven different genotypes amongst the four races of the pathogen (33 genotypes of Foc have been identified worldwide). The identification of Foc in Australian plantations will be continued with VCG analysis and the development of a PCR-based detection system. To improve regulation of quarantine restrictions in Australia and to prevent the introduction of more strains from overseas, we will develop a DNA-based identification system to accurately characterise all strains that occur in Australia and generate a DNA fingerprint database. We will also develop a system to detect the pathogen directly from plant tissue.

Four nematodes are precluded from approved planting material and these are detected in routine testing of root samples. *Radopholus similis* (burrowing nematode) is a major pest of Queensland’s banana industry. Recent studies have revealed the presence of an undescribed species of *Radopholus* in Northern Territory. This and populations of *R. similis* from Queensland vary in their ability to reproduce on a range of cultivars. If new ‘resistant’ cultivars are introduced to manage burrowing nematode, variation between nematode populations is likely to result in ‘failure’ of some cultivars. This project will collect and culture populations from throughout Queensland and test them for their ability to reproduce on representative range cultivars. This will determine the distribution of different pathotypes and the reaction of cultivars.

This project will ensure implementation of practical and reliable quarantine schemes.

**Progress to date**

*Host range of BSV isolates determined*

As reported in June 2001, mealybug inoculation was found to be an inefficient technique for screening large numbers of banana genotypes for susceptibility to BSV. A new approach was therefore adopted to determine the natural host range of the different strains of BSV. The DPI plant virology group has collected 206 specimens of banana streak disease from more than 50 different banana genotypes and 17 countries. This collection was screened using specific PCR assays for six strains of BSV, namely BSV-OL, BSV-Mys, BSV-GF, BSV-Cav, BSV-IM and BSV-Lac.

Positive PCR reactions were obtained with 106 of the diseased specimens. Failure to detect BSV in the remaining specimens may reflect deterioration during storage, the existence of other BSV strains in addition to those tested and/or misidentification of symptoms. In Australia, all strains, except BSV-Lac, were found. BSV-Lac is very uncommon, and only detected in a single specimen from Africa. BSV-OL was the most common strain, being detected in exactly 50% of the specimens and in many different banana genotypes, viz. *Musa* AA, AAA, AAB, AAAB and ABB groups. BSV-OL is known to arise by activation of viral sequences that are integrated into the B genome of banana. The fact that BSV-OL was detected in a Cavendish banana (*Musa AAA* group) at Weipa, north
QLD, suggests that there is natural transmission of this virus by mealybugs. After BSV-OL, BSV-GF was the next most commonly detected strain, being detected in 25 specimens. All cv. Mysore plants were infected with BSV-Mys, and this strain was very uncommon outside this cultivar. BSV-Mys was detected in a cv. Lady Finger plant from Flaxton, NSW, and a Cavendish plant from Kiama, QLD, but in both cases, links could be made with a cv. Mysore plant growing nearby. BSV-Cav was found in Cavendish plants from Daradgee, Babinda and Innisfail in north QLD. These plants had a common propagation history. Outside this group of plants, BSV-Cav was very rare, only being found in one Dwarf Cavendish plant from Bowen, QLD. BSV-IM was also extremely rare; in Australia, this strain was detected in new IRFA hybrids (*Musa* AAB group) originating from the CIRAD (France) breeding program, a Pisang Raja (*Musa* AAB group) plant from north QLD and a single Pisang Awak (*Musa* ABB group) plant from a germplasm collection at Alstonville, NSW.

**Specificity and sensitivity of PCR diagnostic determined for detecting Foc in planting material**

The specificity of the PCR primers for each of the Australian races and VCGs of Foc has been established by screening them against other VCGs and genotypes of Foc *in vitro*. Diagnostic PCR primers have been designed that are specific for the race 1 strains (VCGs 0124, 0125, 01220), race 2 strains (VCG 0124 and 0128), subtropical race 4 strains (VCGs 0120, 0129, 01211) and the tropical race 4 strain (VCG 01213) of Foc.

Procedures for DNA extraction and PCR amplification directly from infected plant material and infested soil have been investigated and optimised. Several different DNA extraction protocols (both published methods and commercially available kits) were tested for plant material and soil, and a method was selected that gives a good DNA yield and minimal inhibition of PCR amplification.

The protocols for DNA fingerprinting analysis and the PCR diagnostic test for the tropical race 4 strain of Foc were collated into a training manual for a workshop coordinated by the CRC for Tropical Plant Protection. The workshop was held at the Northern Territory Department of Primary Industries and Fisheries (NT DPIF) Plant Pathology Department in Darwin, during November 2001. Staff from the NTDPI, WA Agriculture, AQIS and NAQS were trained in fusarium wilt diagnostics and the DNA diagnostic test for tropical race 4 of Foc was implemented in the Darwin laboratory, where several outbreaks caused by this strain of Foc have already occurred.

**Nematology section of project**

The project has finished and the final report is being written. Eight isolates of *Radopholus* spp. from banana crops from throughout the major banana areas of Australia were collected (Darwin, Tully, Bartle Frere, Cudgen Tallebudgera, Pimpama, Red Hill and Crossmaglen). The isolates have been established on carrot cultures at Indooroopilly Research Centre. The isolates were tested on a range of tissue cultured banana cultivars (Williams, Pisang Jari Buaya (PJB),...
SH-3142, Goldfinger and Lady Finger) for their ability to reproduce and tolerate nematodes.

The ability of the nematodes to reproduce on the banana cultivars was significantly different between the different nematode isolates. The isolates of *R. similis* from Tully and Pimpama were able to multiply equally well on all cultivars including PJB. PJB is reported to have some resistance to *R. similis* and has been used in international breeding projects to develop nematode resistant lines. All other nematode isolates had lower reproduction on PJB relative to Williams. Williams was used as the susceptible standard throughout the trial. The resistance to multiplication on banana cultivars, relative Williams, depended on which isolate of *R. similis* was used. While PJB was resistant to most nematode isolates, SH-3142, Lady Finger and Goldfinger also demonstrated some resistance depending on the isolates of *R. similis*. Similar results were obtained when the trial was repeated.

The *R. similis* isolate from Tully was also found to be more pathogenic than all other nematode isolates, except the isolate from Pimpama. The pathogenicity was determined by the nematodes’ ability to reduce the root weight of banana plants. Pathogenicity of the nematode isolate appears to be correlated with the nematodes’ ability to multiply in the roots of the host plant. Again, similar results were obtained when the trial was repeated.

The results suggest that resistance that is being developed in banana varieties could be overcome by some isolates of *R. similis*. This is a strong indication of the presence of pathotypes of *R. similis* in the Australian banana industry. The presence of pathotypes would need to be confirmed by RAPD analysis of the eight isolates of burrowing nematode. If banana cultivar resistance is to be used to reduce the impact *R. similis* has on banana production, sources of resistance, other than PJB need to be investigated.

**Project title:** Banana Fungicide Resistance

**Project duration:** 1 July 1999 - 30 June 2002

**Synopsis of project**

Loss of sensitivity to the demethylase inhibitor (DMI) and benzimidazole fungicide groups in *Mycosphaerella fijiensis* (black sigatoka) is widespread in Central America and has resulted in an increase in the number of fungicide applications applied from about 20-25 to 40-45 per season. A loss in sensitivity was detected in *Mycosphaerella musicola* in the Innisfail banana-growing area in 1996. An eight-fold decrease in sensitivity was demonstrated using a technique developed using conidia. The sensitivity appeared to return to normal over a 6- to 8-month period in the absence of the DMI fungicides. In Central America, where a shift was reported over many years, the sensitivity of the population did not increase or return in the absence of the fungicides. Anti-resistance strategies were developed for all fungicides in consultation with the banana industry and chemical companies.
In this project the sensitivity of yellow sigatoka populations in north Queensland will be determined for the DMI fungicides presently used in bananas to identify any shift in sensitivity before major problems develop as has occurred in Central America. The stability/persistence of any less sensitive populations detected will be monitored over time to enable the anti-resistance strategies to be implemented to reduce the effect of any loss in sensitivity. The validity of the test developed using conidia will be compared to that used for *M. fijiensis* in Central America which uses ascospores. Baseline sensitivity data will be generated for all systemic fungicides presently registered and those in the pipeline to be registered for use on bananas in Queensland.

**Progress to date**

Baseline sensitivity data were established for the compounds benomyl, propiconazole and tebuconazole. This was achieved by collecting wild-type isolates from unsprayed banana plants at least 25 kilometers away from known commercial blocks of bananas to ensure isolates had not been in contact with any spray drift or originated from ascospores from sprayed areas. Baseline data on percent germination were gathered for trifloxystrobin, however, further wild-type isolates need to be assessed to determine germtube elongation, as recently shown in Central America, to be an indicator of small shifts in sensitivity. Baseline EC50 (effective concentration required to reduce growth/germination by 50%) figures for each of the fungicides are as follows: benomyl – 0.045 mg/ml, propiconazole – 0.01 mg/ml and tebuconazole – 0.016 mg/ml.

Since 1999, the north Queensland banana industry has been monitored for resistance or loss of sensitivity to the above-mentioned fungicides. In the 1999-2000 season, approximately 70% of samples tested for “resistance” to benomyl registered moderate to serious shifts (>8 fold increase compared to the baseline EC50). As this high level of resistance was detected throughout the industry, no further testing of samples against benomyl was conducted.

Loss of sensitivity to the fungicides propiconazole and tebuconazole was also detected throughout the north Queensland banana industry. Between 1999-2002, greater than 90% of samples registered with a nil or minor shift in sensitivity to propiconazole leaving <10% of samples in the moderate to serious category (>8 fold increase in the baseline EC50). Results of samples assessed for loss of sensitivity to tebuconazole were the reverse with approximately 78% of samples registering a moderate to serious shift and the remaining 22% of samples in the nil or minor shift category.

Data suggest “resistance” to propiconazole implies 100% cross-resistance to tebuconazole. The reverse, however, is not as high.

A selection of farms that registered a moderate to serious shift in sensitivity to either propiconazole or tebuconazole were monitored on a regular basis to observe if the sensitivity of the *M. musicola* population returned to normal in the absence of the fungicide. In the majority of cases where a decrease in sensitivity had occurred to propiconazole, the population returned to a normal level of sensitivity.
However, where the sample population was tested against tebuconazole, results were not as definitive and monthly data were erratic.

Spray history where possible was obtained for the previous 12- to 18-month period to determine if any practices could have contributed to the loss of sensitivity. In the majority of cases where a loss in sensitivity was detected, the anti-resistance strategy was not followed. The following appeared to contribute to a loss of sensitivity:

- Prolonged use of DMIs (>2 back to back);
- Overuse of DMI fungicides (>6 per season);
- Applications of DMIs made during the ‘DMI free period’ (July to October);
- Applications of DMI fungicides made to severely diseased tissue.

**Project title:** Strategies for management of fusarium wilt of banana

**Project duration:** 1 July 1999 - 30 June 2002

**Summary**

Disease pressures continue to limit banana production in Australia. Fusarium wilt is a disease, which is widespread in many of the banana producing regions of Australia. Fusarium wilt of banana (Panama disease) is caused by a soil-inhabiting fungus, *Fusarium oxysporum* f.sp. *cubense* (Foc), for which there is no commercially viable means of chemical control. Throughout the world, long-term control of this disease is largely dependent on genetic host resistance. Through this project, banana varieties including dessert hybrids and breeding diploids from the four largest international banana breeding programs will be evaluated for their reaction to the two major strains of Foc present in Australia (race 1 and sub-tropical race 4) at separate field evaluation sites. Agronomic data will also be taken from surviving varieties, including the postharvest evaluation of fruit. It should be noted that disease evaluation trials are different to commercial variety evaluation trials, the latter not being within the scope of this project.

The incidence of fusarium wilt in tissue culture-derived plants has been shown by DPI researchers to be higher than that in plants derived from traditional planting material (bits or suckers). It is thought that the sterile environment in which tissue-cultured plants are raised may preclude useful or beneficial microorganisms from establishing in the young tissue culture plantlets, delaying the onset of naturally occurring defenses to soil borne diseases. In a complementary research approach to the field evaluation of banana germplasm, the role of non-pathogenic, endophytic strains of Foc will be investigated for their ability to enhance resistance to Foc in tissue-cultured banana plants. Studies commenced in FR96018 identified some non-pathogenic strains of Foc that afforded levels of protection to tissue-cultured banana plantlets against Foc in small-scale trials. These and new strains were included in this investigation. This research also complements that of FR98006, investigating the potential of mycorrhizal fungi and rhizobacteria for developing healthier banana roots in relation to banana nutrition and resistance to Foc and nematodes. This project also directly relates to FR99037 “Diagnosis
of Banana Pathogens”, in which the host range, geographical distribution and diversity of the different strains or Vegetative Compatibility Groups (VCGs) of the fusarium wilt pathogen is being monitored. Knowledge of the VCGs of Foc in Australia is important for the selection of resistant cultivars for particular locations, depending on the strains present. The known geographical distribution of these VCGs has also enabled the implementation of meaningful quarantine zones to limit the spread of this pathogen by the movement of rhizomes and infested soil. The characterisation of all new outbreaks of Foc enabled the early detection of exotic strains such as tropical race 4 in Darwin, NT.

In addition to the evaluation of microorganisms for improving resistance of banana to Foc, other agents such as plant activators were investigated. For example, BION® is a plant activator that is known to have a systemic acquired resistance (SAR) effect, and has reduced the incidence of fusarium wilt in other crops.

Field-trial evaluation of Musa germplasm for resistance to Foc is time-consuming and expensive. The development of a reliable small plant bioassay will be investigated to enable a more rapid and economical evaluation for new varieties, breeding lines and disease control measures under glasshouse conditions. This test would not replace field-trial evaluation; however, it would be a tool by which the most promising varieties could be selected for evaluation under field conditions.

Progress to date

*Field evaluation of banana varieties for resistance to races 1 and 4 of Foc*

Resistance evaluation at fusarium wilt-infested field sites is ascertaining the reaction of new varieties to Australian strains of fusarium wilt caused by the fungus Foc. Varieties produced by the world banana breeding programs (FHIA in Honduras; EMBRAPA-CNPMF in Brazil, IITA in Nigeria and CIRAD-FHLOR in Guadeloupe) have been imported by DPI for evaluation.

**Evaluation against Foc race 1 (VCG 0125)**

Varieties resistant to Foc race 1 were FHIA-01 (Goldfinger), FHIA-18 (Bananza), FHIA-25, SH-3640-10 (known as Highnoon in South Africa) – conflicting results, TMBx 5295-1 (a Laknau hybrid known internationally as Bita 3).

Varieties susceptible to Foc race 1 were FHIA-02 (known as Mona Lisa in South America), SH-3641 and Lady Finger.

Full term internal ratings for the CIRAD-FHLOR varieties (IRFA -901, -910 and -914) could not be conducted as the plants were removed and destroyed due to development of banana streak virus (BSV) in these varieties after planting.

**Evaluation against Foc race 4 (VCG 0120)**

Varieties resistant to Foc race 4 were FHIA-01, FHIA-18, SH-3640-10, SH-3656, IRFA -909, IRFA -914 and TMBx 5295.

Varieties susceptible to Foc race 4 were FHIA-02, FHIA-03, FHIA-17, FHIA-23,
SH-3641, IRFA-910 and Cavendish cv. Williams.

Evaluation of FHIA-25 against Foc race 4 is underway at the Wamuran field site with Cavendish controls. According to the late Dr Phil Rowe, former head of the banana-breeding program at FHIA, this cooking variety holds much promise for the reduction of chemicals, used to control black sigatoka, and has very impressive yield and other agronomic characteristics.

Postharvest evaluation of fruit of varieties, which are being evaluated for resistance to Foc in infested fields

Fruit of twelve accessions or varieties that survived field challenge with Foc were assessed for postharvest quality. The quality attributes assessed included maturity (green life), pulp firmness and response to ethylene of the green fruit. Ripe fruit assessments included shelf life, internal composition (soluble solids, titratable acidity), firmness and incidence of crown rot, peel splitting and finger drop. The varieties with the best profiles were FHIA-18, IRFA-910, IRFA-914, and SH-3656 (GZ). Key attributes of these varieties were their good shelf lives and ripe fruit compositions that can be expected to win consumer acceptance. A specific potential problem identified in FHIA-18 is its susceptibility to peel splitting and finger drop when ripe. Correct ripening management will be required to protect FHIA-18 from these defects.

Non-pathogenic Foc

Twenty endophytic isolates of Fusarium oxysporum were recovered from healthy banana plants in “wilt-suppressive” soils. In the laboratory, no antagonistic effect was observed in vitro between the non-pathogenic isolates and Foc. However, in pot tests conducted in the glasshouse, four endophytic isolates appear to have provided a significant level of protection against the development of fusarium wilt in Cavendish cv. Williams plants. Plants colonised with these isolates prior to inoculation with Foc expressed either mild symptoms of fusarium wilt or no symptoms at all. Wherever Foc had infected the roots of these plants, a difference in vascular tissue discoloration was observed at the junction of the root and rhizome tissues. The results of these studies are encouraging and further testing, including evaluation under field conditions needs to be conducted.

Evaluation of plant activators

BION® (Acibenzolar-S-methyl) is a plant activator known to have a systemic acquired resistance (SAR) effect. Experiments conducted in controlled environmental cabinets to investigate the ability of BION® to induce resistance in tissue-cultured banana to races 1 and 4 of Foc yielded promising results. This agent significantly reduced disease incidence in tissue culture-derived banana plants.

Due to the results of these experiments, two field trials were planted at both of our Foc field-testing sites (Foc race 1 at Duranbah, NSW and Foc race 4 at Wamuran, QLD) to evaluate the efficacy of BION® under field conditions. In addition, a strobilurin fungicide called Amistar® that had shown promise in
combination with BIONO against fungal leaf and fruit pathogens, such as avocado and passionfruit, was also included in these trials.

At our race 1 field-trial site, three months after planting Lady Finger banana, plants were expressing severe external symptoms of fusarium wilt. Phytotoxic effects were observed in plants treated with the highest rate of BIONO (0.050g/l), which caused stunting of plants.

At our race 4 field-trial site BIONO significantly increased growth of Cavendish plants. This effect could only be due to reduced disease incidence. Unfortunately, during this trial very few plants expressed external symptoms of fusarium wilt and internal assessment of the rhizome was only to ground level, which upon assessment revealed very few infected plants. During this trial leaf diseases were not significant and nematodes are not known to be a problem at this site. Therefore it is possible that if the roots of plants had been examined, fewer infections of Foc may have been observed in BIONO treated plants than untreated plant resulting in the observed growth response. These results are encouraging and warrant further investigation.

**Project title:** Management options for banana bunch pest control

**Project Duration:** 30 December 2000 - 30 December 2003

**Summary**

If left uncontrolled, banana bunch pests can cause serious fruit damage resulting in market rejection and the loss of grower income. Over the past few years, some growers have reported chemical failure to control certain bunch pests. The possibility of insecticide resistance, although not substantiated, is becoming an increasingly important issue to many banana growers. The control of banana bunch pests is primarily based on the strategic use of organophosphate insecticides, which are unsafe to human health and the environment. Controlling these pests is costly and can result in high chemical residues left on the fruit. Investigations are currently under way by the National Registration Authority (NRA) to identify, restrict or eliminate the use of registered chemicals, which have the potential to be harmful to the environment. Reduced dependence on synthetic insecticides is essential to promote sustainable pest management practices and further develop integrated pest management (IPM) in the banana industry. Preliminary research carried out by DPI researchers has identified new naturally-occurring insecticides, which could be effective in controlling these pests. Biopesticides are insecticides based on naturally occurring insect pathogens and are a form of biological control. New insecticides (insect growth regulators [IGRs] and natural botanicals) have also been identified which disrupt insect development. These products are safe to the environment and human health, have minimal impact on beneficial insects and only affect target pests making them ideal for use in IPM. More extensive lab and field research is required to evaluate these products over a range of pests and environmental conditions before they could be recommended for use within the banana industry. This project aims to investigate the efficacy and potential for using biopesticides, IGRs and
natural botanicals for banana bunch pest control. Other control practices to reduce the cost of pest management will also be investigated. This project has the potential to manage insecticide resistance by reducing the dependence on organophosphates for bunch pest management and identifying safer insecticides with new modes of action that are better suited to the development of IPM in bananas. This is in line with the industry’s aim to develop pest management practices which are sustainable and safe to human health and the environment.

Progress to date

A new technique for the mass production of banana scab moth – The development of a successful insect-culturing technique has been achieved for the first time for banana scab moth and has been in operation now for 21 months. This new technique will give us better capability to carry out research against this pest and allow artificial infestation in field trials when natural populations are low and a ready supply of larvae for lab bioassays. An artificial diet has also been successfully developed for this system using soybeans and wheat germ as the diet’s base. This is the first time a successful rearing system has ever been developed to produce large numbers of banana scab moth for research purposes.

Lab assays for banana scab moth - A series of lab trials have now been successfully completed for banana scab moth to examine pesticide efficacy on insect mortality.

Tropical biopesticide assays - Droplet sizes of 1ml were placed on x 4, 1st, 3rd and 5th instar larvae and replicated four times with a control (water and wetting agent) and a standard (chlorpyrifos). The treatments included Metarhizium anisopliae, Beauveria bassiana and spinosad. The chlorpyrifos standard and spinosad treatments were clearly the best performers achieving 100% mortality after 24 hours. Both Metarhizium anisopliae and Beauveria bassiana achieved 100% mortality after 72 hours. Although the fungal pathogens achieved slower insect mortality, there was no significant difference between the levels of damage when compared to each of the biopesticide treatments and the chlorpyrifos standard. Some phototoxicity was observed in both the Metarhizium anisopliae and Beauveria bassiana treatments, possibly due to the oil suspension in the insecticide formulations. These biopesticide formulations may need to be modified before field use but the level of efficacy achieved by these insecticides was quite acceptable.

Residual and ingestion biopesticide assays - These trials looked at the residual and ingestion efficacy of Metarhizium anisopliae, Beauveria bassiana, Spinosad, Baccillus thuringiensis (Bt) and emmamectin. The most effective treatments identified in this trial were emmamectin and spinosad which were equally as effective as chlorpyrifos achieving 100% mortality after 24 hours. The Bt treatment was the next best performer achieving 100% mortality after 4 days for all instars. The Metarhizium anisopliae and Beauveria bassiana treatments were the least effective in these assays and a lot slower acting compared to the other treatments showing that residual efficacy is only partially effective when compared to direct contact. Some phototoxicity was observed on banana fruit caused by both the
*Metarhizium anisopliae* and *Beauveria bassiana* treatments possibly due to the oil suspension in the insecticide formulations. These biopesticide formulations may need to be modified before field use but the level of efficacy achieved by these biopesticides was quite acceptable.

**New insecticides residual and ingestion assays** - Assays have just been completed looking at new insecticides with different modes of action. Treatments included thiamethoxam, tebufenozide, DPX-MP062 and noveluron. Tebufenozide and DPX-MP062 performed equally effective when compared to the standard chlorpyrifos at all instar stages of banana scab moth. All treatments were effective in controlling banana scab moth in the first instar stage, which is the stage that is most realistic in a field situation. As the banana scab moth larvae increased in size, thiamethoxam and noveluron where the least effective treatments in achieving mortality.

**Field trials** - Three field trials were completed investigating (1) insecticides with different modes of action, (2) biopesticides and (3) insecticide impregnated plastics as an alternative to bunch dusting with chlorpyrifos.

**Experiment 1**. Insecticides with new modes of action - in this trial three insecticides were selected with different modes of action and compared to chlorpyrifos applied as a bunch spray. Actara® (thiamethoxam, a Neonicitinoide compound) was selected because of its good environmental profile and general all round control for most insect pests. Confidor® (imidacloprid) was selected for its potential efficacy against thrips. Mimic® (tebufenozide - IGR) was also selected for its potential control against banana scab moth and sugarcane bud moth. Moderate pest pressure was achieved throughout the duration of this trial. Actara® (thiamethoxam) gave the best control against all insects compared to the standard treatment of chlorpyrifos. The results indicate Actara® can be used as an alternative to chlorpyrifos as a broad-spectrum insecticide against all bunch pests although further trials need to verify this. Actara® also has a safer environmental profile and because of the chemical group’s new mode of action may be well for inclusion in insecticide resistance strategies. Confidor® (imidacloprid) had the greatest efficacy against banana rust thrips and banana flower thrips. Mimic® (tebufenozide) was the most effective against banana scab moth and sugarcane bud moth. Further work will be carried out investigating combining various treatments to achieve complete control against all bunch pests.

**Experiment 2**. Biopesticides - The next experiment was carried out to examine the potential of using biological insecticides based on insect pathogens. This initial trial looked at four biopesticides, which included; (1) Success® (spinosad, spinosyns A and D natralytics produced by a *Saccropolyspora spinosa* bacteria), (2) *Beauveria bassiana* and (3) *Metarhizium anisopliae* (insect fungal pathogen supplied by CSIRO insect pathology in Canberra) and Dipel® (secondary metabolite produced by *Bacillus thuringiensis* bacteria. Moderate pest pressure was achieved throughout the duration of this trial for all insect pests. Success® gave excellent control against all insect pests. In this trial, it was the only insecticide that gave 100% control against banana scab moth and banana rust.
thrips. *Metarhizium* and *Beauveria* also performed well when compared to chlorpyrifos. Dipel® was the least effective treatment in this trial, but still performed well against banana scab moth and sugarcane bud moth. Based on these findings, Spinosad, *Metarhizium* and *Beauveria* have the greatest potential as an alternative to chlorpyrifos to control all the major insect pests in bananas applied as a bunch spray. The results from these treatments against banana scab moth and banana rust thrips suggest they may also be used as an alternative to other insecticides when bell injecting. The rate of Dipel may need increasing to improve efficacy and the *Metarhizium* and *Beauveria* formulations may need modification to reduce slight problems of phytotoxicity.

**Experiment 3. Insecticide impregnated plastics** – This trial consisted of a total of eight treatments which included a (1) new biodegradable plastic formulated bunch cover (impregnated with chlorpyrifos at 1%) and three insecticide-impregnated plastic strips which included: (2) SuScon strips (14% active ingredient) (3) Diazinon strips (20% active ingredient) (4) Permethrin strips (8% active ingredient). The (5-6) control treatments consisted of a “bagged no treatment” and a “no bag no treatment”. The standard (7-8) included chlorpyrifos applied either as a bunch spray or dust. The new chlorpyrifos-impregnated bunch covers gave the best overall control for all bunch pests. In this trial, 100% control was achieved against all pests except for sugarcane bud moth. The level of control against sugarcane bud moth was still the best of all treatments. SuScon strips and Diazinon strips gave equal control when compared to the chlorpyrifos standards of bunch spraying and dusting. Permethrin strips were the least effective in this trial but a pest damage decline could still be seen when compared to the controls. Equal control was achieved against banana scab moth and banana flower thrips when compared to the standards. The new chlorpyrifos impregnated bunch covers were the most effective for controlling all bunch pests, possibly due to uniform distribution of the active ingredient (chlorpyrifos), and look promising as an alternative to bunch dusting for the control of all bunch pests. Both the SuScon and Diazinon strips also proved effective against major pests relative to current practices. This could be attributed to the high level of volatility of the insecticides formulated in the plastic. An applicator has been developed for the SuScon strips for easy application of the strip onto the bunch stalk. Permethrin was the least effective in this trial, possibly due to a lower rate of volatilisation of the active ingredient. However, when compared to the control treatment, a pest damage decline was noticed.

**Product registration** – Spinosad, SuScon strips and impregnated bunch covers are due for commercial registration by July 2003.

**Project title:** Management of banana leaf diseases in north Queensland

**Project duration:** July 2000 - June 2003

**Synopsis of project**
Levels of yellow sigatoka (leaf spot) and the spread and apparent poor control of
banana leaf rust is of concern to the north Queensland banana growers. This project aims to examine various chemicals including new types of fungicides for yellow sigatoka control, and investigate the epidemiology and control strategies for leaf rust. Yellow sigatoka is the most important disease affecting bananas in north Queensland and when control is not effective, plants are rapidly defoliated, especially after bunching impairing fruit filling, inducing “mixed” ripening and reducing yields. Leaf rust that was first identified about 8 years ago but considered a minor disease, has spread through the industry and appears to be increasing in significance. There are no control measures for rust.

Current chemical control measures for yellow sigatoka rely on the protectant fungicide, mancozeb and the systemic fungicides, propiconazole, tebuconazole and benomyl. Concerns have arisen recently regarding ‘resistance’ to these systemics and a HRDC/QFVG funded project is examining the problem. A number of ‘new chemistry’ fungicides (strobilurins and SARS) have shown promise for the control of leaf diseases. A range of formulations of mancozeb and oil are used but results are variable. Inoculum control is an integral part of yellow sigatoka management and an understanding of local factors that influence inoculum production is necessary.

This project comprises five components: 1) evaluation of the efficacy of ‘new chemistry’, 2) assessment of the efficacy of mancozeb formulations, 3) assessment of the efficacy of oils for yellow sigatoka control, 4) examination of the seasonal production of ascospores and 5) examination of the epidemiology and control of leaf rust.

**Progress to date**

*Fungicide field trials (new fungicides, mancozeb) at SJRS*

New chemistry evaluation - Treatment applications commenced on 4 March 2001. Twelve treatments comprising seven fungicides and one defence activator used alone and in spray programs with other chemicals were compared to the industry standards mancozeb as Dithane M45® and propiconazole as Tilt®. The final disease assessment was conducted in mid September (about 2 weeks prior to harvest). The disease severity index (DSI) showed that the three strobilurins, Tega®, Cabrio® and Amistar®, and the triazole JAU 6476 were more effective than Dithane®, Calixin® and the Folicur® program.

Mancozeb (formulations x rates) evaluation – Treatment applications commenced on 4 April 2001. Thirteen treatments consisting of four mancozeb formulations at various rates of application were compared. All treatments included an equivalent rate (5l/ha) of paraffinic oil. Disease pressure within the trial remained fairly low. Low disease pressure is often associated with ‘plant crop’ bananas. The final disease assessment was conducted in mid October (about 2 weeks prior to harvest). The DSI showed there was no significant difference between treatments.

*Assessment of the efficacy of oils for yellow sigatoka control*

Five companies provided products for evaluation. These products included various
paraffinic oils, vegetable oil formulations, mixtures of vegetable oils and tea tree oil and the adjuvant Nufilm®. These treatments were compared with the industry standards BP Misting Oil® and Fuchs Spray Oil®. Rates of application of the BP Misting Oil® were also compared making a total of 15 treatments. The standard rate of Dithane® (2.2 kg/ha) was added to all treatments except tea tree oil. This was done at the request of the supplier of the tea tree oil.

An assessment of youngest leaf spotted (YLS), total number of leaves and DSI was made on 16 May following the 6th spray application. Disease pressure in the guard row plants was moderate to severe. Results showed that the paraffinic oils were significantly more effective than the vegetable oils and tea tree oil. The industry standard BP Misting Oil® + Dithane® was also more effective than Nufilm® + Dithane®. The higher rates of application of BP Misting Oil® (8.0 and 10.0 l/ha) gave more effective control of leaf spot than the standard rate of 5l/ha.

Glasshouse techniques for yellow sigatoka and rust investigations developed

The mass production of spores (conidia) of yellow sigatoka on artificial media was successfully achieved in the laboratory. Symptoms of yellow sigatoka were reproduced in the glasshouse under conditions of high light intensity. Initial attempts to develop rust symptoms on inoculated plants were unsuccessful. Research did not proceed any further due to the outbreak of black sigatoka in the Tully valley in April 2001.

Rust fungicide field trials

At the commencement of 2001, contact was made with a number of growers and a suitable trial site (rust had been a problem at this site for a number of seasons, and the site was separate from the rest of the farm so avoiding spray drift) was found at Paul McAvoy’s property at Garradunga just north of Innisfail. Arrangements were made with the grower regarding access to the property and compensation for the loss of fruit sprayed with un-registered chemicals. A broad range of systemic (strobilurins and triazoles) and protectant fungicides were obtained from the chemical companies. Research did not proceed any further due to the outbreak of black sigatoka in the Tully valley in April 2001.

Early in 2002, growers were again contacted regarding establishing the rust control trial. The trial did not proceed due to a lack of leaf rust in the region. This was due to the prolonged dry weather and the intensive de-leafing program in the region.

Project title: Development of bananas with resistance to *Fusarium oxysporum f.sp. cubense* (tropical race 4)

Project duration: 1 March 2001 -30 June 2005

Synopsis of project

The primary outcome from this program will be the effective management of the devastating disease of bananas, fusarium wilt, caused by *Fusarium oxysporum f.sp. cubense* (Foc) “tropical” race 4 through a program approach.
Specific outcomes of this program will include the identification and commercial adoption of a banana variety that is acceptable to domestic consumers and profitable to produce in tropical areas of Australia infected with this strain of Foc. Such varieties will be resistant, or at least tolerant, to this strain of the disease whilst displaying acceptable agronomic requirements and marketability.

A condition of this program is that the conduct of the proposed R&D will not increase the risk of Foc inoculum moving to the wider industry. That is, a further outcome is the minimisation of risk associated with the research of Foc on a site in the Darwin region.

Progress to date

A secure research facility with a capacity to test 20+ varieties of bananas has been constructed and is operational with appropriate protocols in place. A 21 hectares site known as Coastal Plains Banana Quarantine Station (CPBQS) has been fenced and a 2.7 hectares secure area known as Coastal Plains Banana Quarantine Area (CPBQA) has been established within CPBQS.

Construction of the 2.7-meter high earth bund, 2-meter high security fence and associated wash-down pads, internal earthworks and buildings was delayed about 6 months by prolonged wet weather and this has delayed the project overall. Site works were completed on 6 June 2001 and the site was officially opened by the NT Minister for Primary Industries on 9 June 2001.

Appropriate Quarantine Protocols have been developed and were implemented on 22 August 2001. This is to test them for 2 months before inoculation takes place.

All available test varieties have been established within CPBQA and are approaching the size suitable for inoculation. Fourteen varieties have been established and the remaining six are currently completing quarantine procedures and will be established as soon as they become available.

The Management Committee has met regularly, has conducted site inspections and has endorsed the facility suitability and the quarantine protocols.

*Early identification of highly susceptible and possibly tolerant varieties in the parent crop.*

Six susceptible and highly susceptible types and six types, which, at this stage, are resisting the disease under very high inoculum pressure, have been identified.

Criteria 1– Documentation of fusarium wilt rating and identification of susceptible and potentially resistant varieties.

- Pisang Berangan is extremely susceptible and dies before reaching bunch emergence stage in almost all cases. This confirms the Malaysian work.

This has been used to advantage as it was used as the sacrificial interplant to build up inoculum in the site as well as a datum plant.
This variety began showing the first symptoms 6 weeks after being directly inoculated in the field. A further 6 weeks later, some 547 of the 622 directly inoculated plants were showing external symptoms of the disease and most were severely affected.

- Cavendish [Williams 1017] and FHIA-17[944] are susceptible in the test site with 20-25% of test plants at this stage having been rated as positive to Foc tropical race 4 using the INIBAP guidelines and more plants developing symptoms. It is to be reasonably expected that the remainder will develop symptoms in time.

- Foc-susceptible malaccensis selections 845, 846, 848 are proving susceptible in the test site with approximately 50% of test plants at this time being rated as positive using the INIBAP guidelines. It can be reasonably expected that the remainder will develop symptoms in time.

- Cavendish [GCTCV-119-ex Taiwan], FHIA-01[Goldfinger], FHIA-18, FHIA-25 and SH-3460.10 [High Noon] are not showing any symptoms at this stage and could be considered potentially resistant at this stage.

In addition to the visual assessments being done on plants as per the INIBAP guidelines, one sample has been taken from one plant assessed as positive to Foc TR4 in each of the treatments where a susceptible plant has been identified. This sample of pseudostem showing symptoms is being tested in the laboratory for presence of Foc TR4. The laboratory procedures have not yet been completed but preliminary results confirm the visual assessments as per the INIBAP guidelines.

Criteria 2 – Strategy to protect IP and ensure the right to commercialize development with each of the promising variety owners.

Strategy is to get written commercialization agreements with owners of non-public varieties by direct negotiation.

Criteria 3 – Reports of Progress to HAL, Management Committee, National Reference Group. The management committee meets at 6-9 week intervals or as required and receives a full accounting of progress of the project at these meetings.

Copies of this report are being sent to HAL, Management Committee and National Reference Group. A separate report has been sent to QFVG.

**Project title:** Banana tissue culture for industry development

**Project duration:** 1 July 2001 - 30 June 2004

**Summary**

The Australian banana industry needs to address a range of issues in order to maintain and expand its market share. They face a changing consumer focus, more emphasis on environmental protection and sustainability issues as well as increasing pressure from pests and diseases within Australia (e.g. subtropical
and tropical *Fusarium oxysporum* f.sp. *cubense* (Foc) race 4, nematode, yellow and black sigatoka, banana bunchy top virus) as well as from threats of exotic pests and diseases. The Australian Banana Growers Council (ABGC), Banana Industry Protection Board (BIPB, Queensland) and Banana Industry Committee (BIC), New South Wales have identified national research and development strategies to address these emerging problems. The strategies rely heavily on a diverse range of banana varieties. Varieties sourced specifically for Australian R&D need to enter Australia directly through our AQIS-registered tissue-culture facility to safeguard against release of exotic pathogens. Industry requires planting material to be pest- and disease-free and therefore able to be accessed across the domestic quarantine zones and this can only be achieved using virus-indexed tissue-cultured plants. Our laboratory is best able to deliver this outcome.

Current and future research into pest and disease, as well as industry development, all rely on the use of banana germplasm (a diverse range of varieties) The research and support to be provided addresses the provision of banana material, improvements in tissue culture and support of the Quality Banana Approved Nursery (QBAN) Scheme to enable disease free plantlets to be distributed anywhere in Australia. Maintenance of the large number of disease-free banana varieties is managed by tissue culture storage. Plants stored in tissue culture can be multiplied as needed in a short time frame and include varieties that are not grown commercially and therefore not available elsewhere. In Australia, our laboratory is the only laboratory that serves this vital function. There are over 20 current research projects (including black sigatoka exclusion strategies) utilizing banana tissue culture plantlets from this banana germplasm collection. As well, there is an increase in growers wanting to evaluate new varieties to explore their potential in new markets.

**Progress to date**

This laboratory maintains an extensive collection of banana varieties used specifically for industry development. The banana collection is maintained using world’s best practice, at 16 °C to reduce subculture requirements. We currently maintain approximately 400 accessions within our low temperature culture room. To satisfy industry needs, we maintain these varieties “on call” ready to supply plants in whatever quantity is required by researchers or growers. As part of this project, we are looking at ways to improve efficiency of production and quality of plants, with emphasis on germplasm storage and recalcitrant varieties. Since the start of this project, we have been able to improve the condition and quality of this material. We have developed improved methods of medium-term storage conditions, including containment in plastic and increased light levels. We have implemented improved procedures for routine initiation of cultures using dissected meristems rather than shoot tips to eliminate detrimental bacterial contamination. The result has been a significant improvement in the time of rotation of plants as well as quality and multiplication! We are implementing new processes to improve production of recalcitrant varieties. Reduction of apical dominance has been of major importance to some varieties and requires damage to the apical dome when plants stop multiplying.
The field germplasm collection at Centre for Wet Tropics Agriculture has been relocated on-station to rationalise and revitalise it. Approximately 200 varieties are maintained in this field collection. This year, 56 accessions have been re-initiated into the tissue-culture collection using meristem culture. These varieties will replace older, low-vigour accessions.

Approximately 8000 plants were produced this year specifically to support industry R&D. Plantlets were provided in 81 separate consignments produced from 400 different accessions (20 consignments for ongoing research and 61 individual consignments for growers in NQ, SEQ, NSW, NT). Recipients covered the production costs for these plants as part of the cost recovery scheme.

AQIS registration has been renewed to facilitate safe importation of varieties. Importation of new varieties has been facilitated safely and efficiently. This year, 20 new banana accessions have been introduced into Australia via this laboratory. There are currently 37 accessions undergoing post entry evaluation (some introduced last year). Plantlets from these accessions are multiplied and maintained in tissue culture while original plants are grown in DPI quarantine glasshouses at Eagle Farm and evaluated by DPI plant pathologists and virologists before release. The post-entry evaluation process takes between 8 to 12 months. This year, important varieties that have shown resistance to Foc tropical race 4 from the Malaysian banana improvement program have been released for specific research use. The plants have been multiplied and supplied for assessment in the Foc tropical race 4 inoculated field-trial site in the Northern Territory and will be planted in the field collection block for agronomic evaluation.

Plants for variety evaluation have been produced and are in nursery establishment in North Queensland prior to field establishment. Grower evaluation sites for niche varieties are due for planting in September 2002 in North Queensland. Basic agronomic/yield/fruit quality information will be collected. Once the varieties are bunching, a field walk will be organised for growers to attend. In association with QHI Marketing Officer, we have been working with a group of NQ growers doing market R&D for a range of niche banana varieties with particular emphasis on Señorita.

QBAN industry support provided. QBAN continues to expand as an important sector of the Australian Banana industry. All of last year’s facilities renewed membership. This year, we have 30% more fully accredited QBAN facilities than last year. There are currently 24 QBAN facilities, 5 commercial laboratories in Queensland, 4 commercial laboratories in NSW, 6 commercial nurseries in Queensland and 3 nurseries in NSW. There is one DPI Research tissue-culture laboratory and 5 DPI- and 1 University-registered research facilities.

QBAN connections newsletter was written and distributed July 2002.
Project title: Banana harvest forecasting project

Project duration: 3 January 2002 - 3 January 2003

Summary

The aim is to develop a system to allow the prediction of fruit production levels throughout the year 3 months in advance and to provide industry with overall general production figures 3 months in advance, and to set-up a system to aid individual growers with the management of their bunch production data, which can allow them to forecast banana harvest yield 3 months in advance.

The project aims to assist growers with the use of forecasting to improve farm management and planning, and to provide stakeholders, as directed, with future estimates of production in general.

The rate of filling of a banana finger is temperature dependent. The objective of this one-year project is to examine the relationship between temperature and the rate of filling of banana fruit with a view to using this to accurately predict harvest volumes over a 3-month time frame.

The temperature can be used in different ways. The use of heat sums is a standard way to forecast production volumes in other fruit production systems. We want to monitor temperatures in five demarcated growing regions in north Queensland and use this to produce heat sums for those regions and investigate suitability for a forecasting system. Heat sums are a combination of the time for a particular event to occur and the average temperature experienced during the period monitored.

With bananas in particular, the rate of filling of the banana fruit is thought to be linearly dependent on temperature over normal average field temperatures (16-30 °C) and so, this will be investigated for possible use as a forecasting method. Finally, plantation-specific systems used overseas will be investigated for suitability in the Australian production situation. This is based on the seasonal average interval between bell emergence and harvesting and is dependent on the accumulation of good, accurate data from growers for accurate forecasting.

The aim is to set up a system that is simple and quick for growers to use. They would input their bell injection and harvest data every 2 weeks and together with temperature independently gathered, a forecast of number of bunches will be calculated. The grower can also input his expected bunch/box ratio over the 3-month period and a forecast of the number of boxes will be given. The option to add their figures to a general production figure may be possible.

Project title: PCR primer verification and analysis of the black sigatoka outbreak in Tully

Project duration: 1 July 2002 - 31 December 2003

Summary

In April 2001, an outbreak of black sigatoka disease on banana occurred in the
Tully region. A DNA-based diagnostic test capable of distinguishing black and yellow sigatoka fungi has been developed as part of a CRCTPP project. This test has proved very useful but we now propose to:

(i) Study diversity within the pathogenic population in order to understand how this outbreak may have arisen, whether from single or multiple incursions and if there is any link with previous incursions. DNA is available from banana leaves with suspected black sigatoka lesions. PCR primers will be developed which give specific DNA products and comparisons will be made between these products for different isolates collected during the outbreak. This will allow us to analyse how the outbreak developed and thus form a better understanding of this disease and implement plans for future eradications, if required.

(ii) Further develop the diagnostic test by ensuring that the primers detect all major variants of the fungus, such as the suspected new species *M. eumusae* that causes black Sigatoka-like symptoms.

Because of the proximity of Australia to the proposed centre of origin of the various *Mycosphaerella* pathogens on banana, a larger screening of isolates of *Mycosphaerella.fijiensis* and other *Mycosphaerella* spp. will be undertaken to account for any variation. The primers used to detect black sigatoka will be tested against all these samples to verify specificity for *M.fijiensis* and *M. eumusae*.

This study will help ensure that the primers being used during the Tully black sigatoka outbreak will detect possible future incursions of black sigatoka, which may differ in sequence.

**Progress to date**

**Milestone (2) due 30 January 2003**

Description: Initial amplification and analysis of sequence of ITS region of *M. fijiensis* of Australian isolates.

Criteria: Isolates of *M. fijiensis* collected, cloned and sequence data of the ITS region of representative isolates.

**Towards milestone 2**

One researcher is focusing on assessing the diversity of the *M. fijiensis* isolates implicated in the Tully incursion. He has examined the ITS sequence (a conserved region) of isolates from the Tully incursion and compared this with isolates of *M. fijiensis* previously collected in the Torres Straits and from earlier incursions from Cape York and also with some samples of *Mycosphaerella musicola* (yellow sigatoka agent) and some samples isolates of other *Mycosphaerella* species. We have requested DNA samples from the collection held by Dr Jean Carlier of CIRAD in France for a range of *M. fijiensis* isolates, especially from the Pacific Islands and PNG. Very preliminary data indicate that the Tully incursion has a narrow genetic base, perhaps indicating that the outbreak arose from a single source.
Another researcher is focusing on further optimisation of diagnostic PCR primers to differentiate black and yellow sigatoka. Recently, sequence data have become available for *M. eumusae*, the causal agent of *eumusae* leaf streak disease, which has similar characteristics to black sigatoka. To ensure that PCR diagnostic can detect and distinguish this new variant, new primers are required for routine screening. Fluorescent PCR is being considered as alternative detection platform providing a faster and more sensitive assay.

**Project title:** Australian Bananas magazine – R&D section – Technology transfer

**Project duration:** 1 November 2001 - 30 July 2003

**Summary**

Every year, research projects are undertaken for the banana industry by various institutions and researchers throughout Australia. Dissemination of these results is often in the form of a presentation and/or final report delivered by the researcher at the end of the project. The published report is delivered to the relevant industry bodies.

In addition, many past reports are relevant to immediate issues that are occurring in the industry and it is often important to re-focus attention on past research and apply the finding to current situations.

The Australian Banana Growers’ Council is seeking, through its magazine Australian Bananas, to keep growers in all regions of Australia, informed of research results, research that is relevant to current and emerging situations and to deliver progress reports on continuing projects.

The Australian Banana Growers’ Council is also seeking information about the industry of technology that has been taken up by other growers.

Output from the initiative would be a 25% representation of R&D projects and information articles within the bi-annually published Australian Banana as magazine, with a comprehensive listing of R&D projects annually and feature articles of practical application of those initiatives. The July issue would be 48 pages (12 pages R&D) and the December issue 64 pages (16 pages R&D).

The expected outcome is that growers will be able to read the theory of particular initiatives and read about growers that are applying either the technologies featured in the magazine or other technologies that have been represented in the magazine in the past. This would also provide growers with a contact person with whom to talk over some of the issues. Surveys have suggested that growers obtain much of their information from other growers. It is hoped that in this way new technologies that are effective would be better taken up and applied.

**Progress to date:** 5 editions of Australian Banana magazine published

**Project title:** Benchmarking the Australian Banana Industry

**Project duration:** 1 November 2002 - 1 November 2003
Summary

This programme addresses the issue of improving the performance of banana growing operations by providing growers with the necessary information to assess quickly and easily their farm’s performance based on Key Performance Indicators (KPIs). By monitoring these KPIs over a period of time and comparing them against a farm’s past performance, against others in the same region, against other regions and against their own targets, growers can obtain a picture of how their operations are performing in relation to the wider industry. As the system is able to return information quickly, growers can see almost immediately where changes they have made have had an impact on their operation, whether in relation to production or labour management.

The project delivers against R&D Priority “Information for Good Management “ 1.1.2 (a priority 1 issue identified in the National R&D Plan Revisions 26/4/2001) and is further enforced in the draft and R&D plan delivered in July 2002 under the following headings:

6.1 “Increase the quality of industry intelligence available to growers at the grassroots level to enable them to make more informed business decisions utilising the national Benchmarking Project.”

11.4 “Take a leadership role in financing and directing of R&D expenditure.” Benchmarking will be an invaluable tool providing insight in to where R&D funding is most needed.

Both 6.1 and 11.4 were identified as “High Priorities” in the Draft National Strategic and R&D Plans.

Progress to date

No Milestones have been completed as yet.
Data entry forms have been developed.

Project title: Identification in banana of defence genes and analysis of their induction by beneficial microorganisms, to confer resistance to soil-borne pathogens.

Project duration: 1 July 2002 - 30 June 2005

Certain non-pathogenic strains of the fungus, Fusarium oxysporum, and certain bacterial isolates (identified at UQ and QDPI) provide protection to banana plants from infection by the fusarium wilt fungus (Fusarium oxysporum f.sp. cubense [Foc]) and the burrowing nematode (Radopholus similis). The presence of such beneficial microorganisms may be the underlying component in suppressive soils where banana plants appear to be protected from these soil-borne pathogens. This may also explain the problem of tissue-cultured banana plants being more susceptible to fusarium wilt and to R. similis in the first year of planting cfr. non-tissue cultured plants; tissue-cultured planting material may lack the beneficial micro-organisms.
We intend to investigate how this protection is conferred by determining if plant defence genes are triggered by the presence of these non-pathogenic microorganisms. Initially, plant defence genes will be isolated in banana. Plants will be challenged with pathogenic microorganisms (Foc and \textit{R. similis}) and with beneficial microorganisms to determine if the latter is triggering a systemic defence response and if so, whether it is sustainable.

By identifying the mechanisms by which these non-pathogenic microorganisms confer resistance to Foc and burrowing nematode, we will be able to manipulate these beneficial microorganisms to confer an effective sustainable control against Foc and the burrowing nematode, whether applied in the field and/or to tissue culture material.

In addition, a wild line of banana (\textit{Musa acuminata} subspecies \textit{malaccensis}) will be investigated further to determine if a putative specific defence gene already identified in these lines is associated with resistance to Foc. Identification of a defence gene unique to the resistant \textit{malaccensis} plants would have implications for the production of resistant transgenic banana lines.

**Progress to date**

One scientist has been awarded a DPI/UQ scholarship to work on this project.

Putative defence genes have been identified and work is in progress to verify their involvement in a plant defence response.

\textit{M. acuminata} ssp. \textit{malaccensis} lines are currently growing at the University’s farm and crosses will be undertaken in the coming summer months.

**Project title:** Soil and root health for eco-banana production

**Project duration:** 1 July 2002 - 30 June 2005

**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 biological, physical and chemical soil 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 they 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 biological, physical and chemical soil 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 3-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 of 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 oxysporum* f.sp. *cubense* (*Foc*), 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.

**Progress to date**

The project has not officially started due to the delay in finalising approval from HAL and agreement contracts. Some preliminary work has commenced and protocols have been established for conducting trials in north and southeast Queensland. A soil health kit has been delivered from the USA, which will form the basis of the kit that will be made available to banana growers. The logistics of how this will be used in the field are currently being determined.

Some pre-plant amendments have been collected, such as cattle paunch (abattoir by-product), mill ash and sludge. A small pot trial has been conducted on the use of paunch material supplied from the Innisfail meat works. The use of paunch material was able to increase the leaf area of banana plants relative to untreated soil. Paunch was not able to suppress nematodes in the soil in the 8-week pot trial.

A preliminary pot trial investigating the impact of soil compaction on the growth
of banana plants with and without nematodes has been completed. Plants growing in a soil with a high bulk density (compacted soil) had less chord roots than plants growing in a soil with low soil bulk density. The amount of chord root was significantly correlated with the growth of the plants. Plants with lesser chord roots weighed less and were smaller than plants with a larger mass of chord roots. The weight of root hairs was not related to the growth of the plants in this trial. Plants growing in a soil with a high bulk density tended to have the corm sitting on the soil surface rather than in the soil. Nematodes were also related to reduced plant growth. More nematodes were found on smaller plants with smaller root systems. The bulk density of the soil appeared to be the major factor limiting plant growth, with nematodes being a secondary factor.

Seeds from 12 interrow pasture species have been collected and are currently being tested for their ability to host burrowing nematodes at the Indooroopilly Research Centre.

Selection of strains of beneficial microbes has been made to inoculate tissue culture bananas to plant in the field. A commercial growth promoting rhizobacteria that is currently available will be included in the trial.

**Project title:** Market-based analysis of constraints to banana industry development in Indonesia and Australia

**Project Duration:** July 2000 - June 2002

**Synopsis of project**

This project will develop and use a participatory process to identify the major constraints to the competitive performance of a horticultural industry in Indonesia and Australia to:

- assist in industry development, and to
- more effectively direct R&D to priority areas with the greatest potential for improving producer/smallholder profitability.

The project will test the usefulness of product market performance (how well the product meets customer requirements for quality, volume and price) and supply chain management (management of the product from planting to consumption) both as drivers of industry development and to guide the contribution of R&D to industry development.

Competitive pressures are rising throughout the food sector. To be successful in this environment, producers and product handlers must actively collaborate to manage the quality, quantity and price of their product to meet changing consumer preferences. Industry profitability depends on efficiently managing factors such as the costs of production, reduction of waste, introduction of new technologies, and impacts of change in the socio-economic environment. These factors must be managed, not just by producers but by all participants in the supply chain of horticulture industries (from producers/smallholders to product handlers and marketers) to provide the product that the market demands.
Research and development agencies play a key role in horticulture industry development. If R&D can impact on those aspects with most potential to increase industry profitability, the maximum benefit to industry development and the greatest return for the R&D investment dollar can result. Discussions with Asian colleagues have indicated a similar need to target R&D efforts, with additional consideration for ensuring flow of benefits to smallholders.

The project will document the system characteristics (from the market back to production and R&D) of a selected horticultural industry (banana). The research approach will utilise the systems assessment methods of La Gra (1990), and the participatory approach advocated by Scoones and Thompson (1994), and will draw on the proposed modules of the Business Development Planning approach developed by Cull et al. (1998). Key participants in the supply chain will generate the data and conduct the analysis of opportunities for improvement in supply chains, working from existing procedures, expertise and experience in the banana industry in Indonesia and Australia. Emphasis within the Indonesian activities will be on the delivery of benefit to smallholders.

It is possible that large companies (e.g. Chiquita) have carried out these types of studies; however the methods and results are generally commercial-in-confidence. Involving these companies would require similar restrictions. International experience indicates that government assistance is required to encourage and facilitate chain development, and to ensure public availability of methodologies, etc.
The banana industry status in Bangladesh

Md Shahidul Islam* and Md Abdul Hoque

Bangladesh is an agricultural country, which lies between 20.34 and 26.38 °N latitude and 88.51 and 92.41 °E longitude. The country has a total area of 147,570 square kilometers with a population of about 140 million. The land can be classified as 80% flood plain, 12% hilly areas and 8% terrace soils. The pH of soil ranges between 4.5 and 8.5. Bangladesh enjoys subtropical monsoon climate with temperatures ranging from 4 °C in winter to 42 °C in summer and an average temperature of 27 °C. July is the hottest and January is the coldest month. Cold waves are frequent in winter. Low temperature for about 2 months causes injury to banana, particularly in the northern part of the country. Annual rainfall varies from 1000 to 2500 millimeters. Three quarters of the rainfall occurs in the hot and humid months of May to September.

Banana industry status

Area and production

Banana is the number one fruit in Bangladesh considering its year-round availability, popularity and production. It accounts for 43% of the total fruit production from 22% share in area. Total production of banana is estimated to be 625,000 tonnes from 39,600 hectares. The average yield of banana is 16 tonnes per hectare, which is lower, compared to other banana-producing countries in the world. Area and production of major fruit crops excluding palm are shown in Table 1.

Uses

Banana is a rich source of calories. Dessert bananas are eaten as fresh fruit while plantain is a good vegetable available throughout the year. Ripe banana mixed with rice and milk is the traditional dish for Bangladeshi. It is used in preparing cakes and other delicious foods. Banana is often the first solid food fed to infants. Plantain has a great demand in the urban areas during the lean period of vegetables from May to October. It is used in fish curry and also mashed with spices. Its green peel is also mashed and eaten. It has medicinal value too.

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Consumption and trade

Almost all bananas produced in the country are consumed in the domestic market. The export markets have their standards and to achieve them, efforts have to be directed to producing good quality fruits. A small quantity of banana is exported to the Middle East countries. No statistical information is available on banana export. Usually, banana passes two or three hands before it reaches the consumer. Small farmers usually sell their produce to middlemen or collectors in the village who then sell the bananas to wholesalers. Retailers and hotels/restaurants will then obtain bananas from the wholesalers. Finally, fruits are sold or served to consumers. Sometimes, retailers obtain the bananas directly from the farmers and sell them at the roadside fruit stalls or markets. As a result, farmers are deprived of their actual price.

Country’s nutritional status

Malnutrition is widespread in the country. The average food intake is deficient in calories, vitamins and minerals. Banana, the cheapest fruit of Bangladesh can improve the situation.

Cultivars

Table banana. There are a number of cultivars of banana in Bangladesh. Among them, Amritsagar, Sabri, Champa and Kabri are the commercial cultivars. The other cultivars are BARI Kola 01, Mehersagar, Dudsagar, Agniswar, Genasundari, Kanaibashi, Basrai, Binisuta, etc. Horticulture Research Centre has 18 cultivars/landraces of table banana in its collection. Besides, there are different types of

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (000 ha)</th>
<th>Production (000 t)</th>
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<tbody>
<tr>
<td>Banana</td>
<td>39.6</td>
<td>625</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>26.7</td>
<td>267</td>
</tr>
<tr>
<td>Mango</td>
<td>50.4</td>
<td>187</td>
</tr>
<tr>
<td>Pineapple</td>
<td>13.8</td>
<td>149</td>
</tr>
<tr>
<td>Watermelon</td>
<td>11.8</td>
<td>96</td>
</tr>
<tr>
<td>Guava</td>
<td>9.8</td>
<td>46</td>
</tr>
<tr>
<td>Papaya</td>
<td>5.6</td>
<td>41</td>
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<tr>
<td>Ber</td>
<td>4.2</td>
<td>15</td>
</tr>
<tr>
<td>Litchi</td>
<td>4.8</td>
<td>13</td>
</tr>
<tr>
<td>Citrus fruits</td>
<td>5.0</td>
<td>9</td>
</tr>
<tr>
<td>Other fruits</td>
<td>6.0</td>
<td>21</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>177.7</strong></td>
<td><strong>1469</strong></td>
</tr>
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seeded cultivars growing in the homesteads, roadsides and forests all over the country. These are tall plants, hardy and drought tolerant. It takes long time to harvest. Most of those cultivars produce sweet fruits, which are used as baby food, dessert and ingredient in baking cakes. Its inflorescence is eaten as delicious vegetable.

**Plantain.** Nine distinct genotypes of plantain have been 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 has been found superior to all in terms of 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.

The important banana cultivars grown in Bangladesh are described below:

**Amritsagar (AAA).** Amritsagar is the best table banana in Bangladesh. It fairly resembles the internationally reputed banana Gros Michel, which once occupied 63% of the world market. Plants are medium-sized, weak and cannot withstand strong wind. The ripe banana develops a bright yellow colour. The pulp has a good taste. The average bunch has 5-7 hands and 12-13 fingers in each hand.

**Sabri (AAB, Syn: Malbhog, Anupam, Martaman).** This is a favourite table variety. The plant is tall and can be identified by the yellowish green pseudostem with brownish blotches, reddish margins of the petiole and leaf sheath. The average bunch weight is about 10 kg. A bunch contains 85-120 fingers. Fruits are medium sized with a thin peel, ivory-yellow in colour, firm in texture, sweet and tasty. It is highly susceptible to fusarium wilt, which is a threat to its production and cannot be cultivated more than two to three times in a ratooning system. The other demerits are easy dropping of ripe fruits from the hand and formation of hard lumps in the pulp. This variety is widely grown in the north and western areas of Bangladesh.

**Champa (AAB).** It is one of the hardiest tall cultivars grown all over the country. But its cultivation is widespread in Chittagong and Chittagong Hill Districts. It can be grown under rainfed condition or with scanty irrigation. The plant is resistant to fusarium wilt and fairly resistant to bunchy top disease. Fruits are small in size with thin peel, creamy pulp and sub-acid taste. Fruits turn golden-yellow when ripe and have excellent keeping quality. The bunch contains 150-250 fingers and its weight is about 16 kg.
Mehersagar (AAA). The plant is medium-dwarf. Fruits are large, greenish to dull yellow colour when ripe. The flesh is very soft and sweet. The keeping quality of fruits is poor and the market price is lower. The average bunch weight is about 15 kg. It is susceptible to leaf spot diseases.

Kabri (AB). Kabri is known by different names such as Bangla, Shail, Thutae, Manua, etc. The plant is hardy and can be grown without much care. The fruits are very sweet, with a light yellow skin colour and contain a few seeds in most cases.

BARI Kola-01 (AAA). Plants are semi-dwarf and produce bunches 23.7 kg in weight with 9-11 hands. Fruits are medium to large (150 g each), bright yellow and sweet in taste.

**Production constraints**

*Production practices*

Banana production in Bangladesh can be categorized basically 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 as perennials in homestead areas and production is not seasonal. Practically no fertilizer or pesticides are applied.

In a mixed-crop production system, banana plantations are 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.

*Planting materials*

Quality planting material is of prime importance for banana production. But most growers are not aware of the sucker quality. Suckers are mostly collected from old orchards without knowing their disease status. Ultimately, the growers fail to produce a good crop. Biotechnology division of BARI has developed the micropropagation protocol of banana. The performance of tissue-cultured plants was also demonstrated in some areas of the country. Tissue-cultured plants showed better performance with respect to yield and quality of fruits.
Training programmes were organised for non-government organization (NGO) personnel on the technique of micropropagation. Some NGOs are producing banana plantlets on commercial basis.

**Major pests and diseases**

In Bangladesh, banana-scarring beetle is a serious problem, which causes scars on the fruits by feeding on young flowers and fruits. The fruits affected by this pest have poor market acceptability. In case of severe incidence, yield is also reduced. A high incidence of scarring beetle was observed in table banana varieties in ratoon crop. The growers have been applying DDT and other systemic insecticides directly on the bunch to protect fruits from beetle. Bagging by polyethylene before opening of the first hand was proven successful in controlling banana beetles. Mites and thrips cause considerable damage to flowers and fruits but are not alarming with a few cases of sporadic incidence. Banana aphid is widespread and causes damage through transmission of Banana Bunchy Top Virus (BBTV).

Fusarium wilt and sigatoka leaf spot are the serious diseases of banana in Bangladesh. Table variety Sabri as well as plantain cultivars are seriously damaged by fusarium wilt with a threat of extinction. The use of disease-free planting materials and improved drainage system can prevent infection. Most of the table and plantain cultivars are susceptible to sigatoka. Tilt and Bavistin are found effective against the disease. But farmers rarely spray their plants. Recently, Banana Streak Virus (BSV) and Banana Bract Mosaic Virus (BBrMV) have been found to be on increase in the country but no attention was paid to it yet. Only BBTV is known to commercial growers and rouging is being done by them. Tissue-cultured plants can play a vital role against this serious disease. Nematodes are also a problem in banana, but no research work was done in this area.

**Environmental factors**

Cyclones, drought, flood, cold temperature, etc. are commonly experienced stresses in different banana-growing regions. The southern part of Bangladesh is cyclone prone, causing occasional heavy production loss. The eastern part is subject to monsoonal damage. In winter, vegetative growth of banana is reduced and bunches are underdeveloped because of low 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.
Current banana R&D activities/programmes and institutions involved

Research addressing the current problems

- Introduction and evaluation of improved varieties/landraces. Eighteen accessions of banana were acquired in 2000 from INIBAP Transit Centre (ITC) through INIBAP. Out of these, 15 accessions were planted in the field for sigatoka disease and performance evaluation under International *Musa* Testing programme (IMTP) Phase III. Two more accessions will be received soon. It is expected that from the collections, variety(ies) will be developed and released for commercial cultivation in Bangladesh.

- Collection and maintenance of local germplasm. Twenty-eight accessions were collected for characterization and conservation in the field. The collection is being continued.

- Improvement of local germplasm for hilly region through clonal selection.

- Soil nutrition management. Banana is a quick-growing plant. It requires sufficient nutrients for its growth. In hilly areas and homesteads, bananas are being grown without any fertilizer. Only the commercial growers use fertilizers but not properly, although there is a recommendation for it (Fertilizer Recommendation Guide, 1997). Most of the growers use high amount of phosphate and urea but low potash. Effects of macronutrients on banana were studied at some locations but not micronutrients. Thus, micronutrient requirements for banana under Bangladeshi condition is yet to be standardized based on research findings. At present, deficiency of zinc and boron is exhibited in the field.

- Studies on water management. In hilly areas local cultivars are grown under rainfed conditions while flood irrigation is practiced in commercial plantations. Research has been initiated on efficacy of drip irrigation system in banana.

- Postharvest handling. Bananas are transported to the nearby markets usually by bicycles, tricycles, wheel barrow, boats and shoulder carriers. Trucks are used for distant city markets. About 20-30% of the fruits are damaged due to heavy pressure on the bunches and rough handling during loading and unloading. 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 burning
rice husk to banana covered with polyethylene film for 12 hours. Some businessmen also use ethrel to hasten ripening. No processing industry for banana is developed in the country. Research on packaging and ripening of banana has been initiated to minimize postharvest losses.

- Crop protection programme. A programme has been developed for collection and identification of different types/races of nematodes and *Fusarium*-causing diseases in banana.

*Development activities*

- To promote banana production and improve fruit quality, field days and training programmes were organized for the banana growers, NGOs and extension personnel.
- The bagging technology against beetle was disseminated through mass media.
- A good number of tissue-cultured suckers of commercial cultivars was distributed from GO and NGO laboratories.
- The advantage of using organic fertilizer on banana was demonstrated in the farmers’ fields by a fertilizer company in collaboration with BARI.

*Institutions involved in banana research*

Research on banana is conducted at the Horticultural Research Centre, BARI under the NARS. Bangladesh Agricultural University (BAU) and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) are also engaged in research activities on banana.

*Opportunities and thrusts*

*Opportunities*

Banana is a popular fruit in the country. It is the only fruit which is within the buying capacity of the poor people. Therefore, it is of prime importance to increase production to meet the demand of the country. The following are the opportunities to improve the present situation of banana industry in Bangladesh:

- Utilization of hilly areas for banana cultivation;
- Intervention of modern varieties and technologies for both plain and hilly areas;
- Use of improved cultural practices;
Reduction of postharvest losses

There is also possibility to export fresh banana and its products.

Thrusts

Research thrusts have been given on variety improvement, production of disease-free planting materials, disease management and postharvest management of banana. Emphasis has been given on field days, demonstration and training programmes for quick dissemination of the technologies. Prime importance has also been given to the maintenance of disease-free mother plants of commercial cultivars and released varieties for large-scale multiplication and distribution to the growers.

Proposed areas of collaboration

Collaboration for banana research is needed in the following fields:

- Variety improvement through germplasm exchange;
- Banana diseases (identification, yield loss assessment, indexing and management);
- Banana sucker multiplication through tissue culture;
- Postharvest studies (handling and processing);
- Human resources development (training, visits, higher studies, etc.).
An overview of the production and banana research in Cambodia

Men Sarom*

Introduction

Cambodia is a country in Southeast Asia in the southwestern corner of Indochina. It occupies a compact territory covering 181,035 square kilometers. The country is extended in latitude between 10-15 °N and in longitude between 102-108 °E. To the north the country is bordered by Thailand and Laos, to the east and south by Vietnam, and to the west by Thailand and Gulf of Siam.

Cambodia has a tropical monsoonal climate with defined dry and wet seasons. The dry season is from November to April, and the wet season is from May to October. The annual rainfall ranges from 1250 to 4000 millimeters. It is low in the central plain and increasing towards the Gulf of Siam. The mean temperature ranges from 21 to 35 °C, with the highest temperature in April (30-35 °C) and the lowest in January (21-25 °C). The central plain is the hottest spot in the country and it is cooler in the east and southwest regions. Across the country, photoperiod ranges from about 11 hours 14 minutes to 13 hours 01 minute with the shortest daylength occurring in late December and the longest in June (List 1958).

Cambodia is a country of 12 million inhabitants with an annual population growth rate of 2.4%. Cambodia is predominately a rural economy with more than 84% of the active Cambodian population rural or agrarian. Most are farmers. In 2000, agriculture contributes approximately 34.1% to the gross domestic product (GDP) with a further 25.5% coming from industry and 40.4% from services (MEF 2001). Agriculture contribution to the GDP has decreased from 44.7% in 1994 to 34.1% in 2000, while industry increased from 15.0% in 1994 to 25.5% in 2000.

Within the agricultural sector, crops are the main contributors to the GDP. Rice is the main crop followed by maize, beans, vegetables and fruit crops. Within the last group, banana, or Chek in Khmer, plays a very important role in the daily diet of the people.

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Banana industry status

Banana plays a very important role in the lives of many Cambodians. Apart from the daily diet that it can provide, banana is a highly valued fruit that is used very frequently in the religious ceremonies. It is a healthy fruit crop and is used in preparing many dishes.

In Cambodia, the date when banana was first grown is not known. Nevertheless, as the country is located within the region of the centre of origin of banana, genetic diversity of the crop is very high. Many landraces are found as well as many wild species. Unfortunately, no study has been conducted and collection has not been carried out.

Banana is still grown in smallholdings with its number varying from a single hill to few hundreds. The crop is normally planted close to the house where care can be taken. Banana is grown in almost all types of soils, but more productive crops are found in the regions close to the rivers and in the central and northeast highland regions of the country where red soil is prevalent. Due to the scale of its production, official statistics on the area, volume and yield are not possible to collate.

Commercial cultivars

There are several major commercial cultivars planted in the country. These are:

**Chek Namva.** This is the most popular cultivar in the country. Its production exceeds all other types of banana and there are a lot of recipes using this variety. The male bud is used as vegetable, fresh or cooked. Leaves are used for packing and wrapping. Several subtypes of Chek Namva are found such as Pluk, Preng and Phnom.

**Chek Ambong.** The production area covered by the cultivar is largest in the country. It is obviously the sweetest banana with mild aroma. It has the biggest bunch, hands and fingers among others. There are several subtypes of Chek Ambong like Kiev, Pluk, Voar, Toeu and Yuon.

**Chek Pong Moan (chicken-egg banana).** Chek Pong Moan is the most delicious and is the most expensive one in the country. Two subtypes of Chek Pong Moan are listed; these are Krachak Andoek and Pluk.
Chek Nuon. This is similar to Chek Pong Moan but not as delicious and larger in size. The skin is thin and the stem is similar to that of Chek Pong Moan.

Chek Meas Sgnuon. This is similar to Chek Nuon but has different taste. The fruits have sweet-sour taste.

Chek Teuk (water banana). By its name, this banana is more tolerant to waterlogging, but its fruits have no commercial value. It is grown mainly in the low-lying areas where water logging is a problem and where no other types of banana can be grown.

Chek Snap Mouk (masked face banana). This banana can only be found in some areas. The fruits are big and are eaten boiled when they are ripe.

Chek Muoy Roy Snit (one hundred hands). This type of banana has no commercial value but it can be a good genetic source for cultivar improvement. Many hands rise from the stalk but fruits are not fully developed.

Chek Chvea. It is a seeded banana. It is grown in farmers’ backyards but normally far away from the house. It is believed that this banana has the power to attract the spirit and so it is not advisable to grow it next to the house.

Chek Tes (decorative type). This is a decorative banana and is grown mainly for its nice flowers. The flower can be red or yellow.

Uses of banana

Banana is a very important crop for Cambodians. All parts of the crop are used, but that depends on the type of banana grown. Table 1 presents some of these uses.

Production constraints

Major pests and diseases

There are many problems associated with banana plantation, but as no research has been conducted in this area, the causes of those are still unclear. The only problem that has been widely reported is fusarium wilt.
Table 1. Uses of the different parts of commercially-grown banana cultivars in Cambodia.

<table>
<thead>
<tr>
<th>Banana cultivars</th>
<th>Stem</th>
<th>Leaves</th>
<th>Male bud</th>
<th>Fruits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chek Namva</td>
<td>Can be used as food (fresh and cooked) and feed (for pig and cattle)</td>
<td>Used as wrapping materials</td>
<td>Used as fresh salad or cooked</td>
<td>Used both green and ripe. When green, it is used for cooking. Ripe banana can be eaten fresh, fried, boiled or in many different forms of preparations.</td>
</tr>
<tr>
<td>Chek Ambong</td>
<td>Occasionally used as cooked recipe</td>
<td></td>
<td></td>
<td>Mainly used as dessert because of their sweetness and mild aroma. Eaten as fresh ripe fruits only.</td>
</tr>
<tr>
<td>Chek Pong Moan</td>
<td></td>
<td></td>
<td></td>
<td>The most delicious banana. The fruits are small, but have very tasty flavour and texture. Eaten as fresh ripe fruits only.</td>
</tr>
<tr>
<td>Chek Nuon</td>
<td></td>
<td></td>
<td></td>
<td>Mainly used as dessert because of their sweetness. Eaten as fresh ripe fruits only.</td>
</tr>
<tr>
<td>Chek Meas Sgnuon</td>
<td>Similar to Chek Nuon, but the ripe fruits are more acidic. Eaten as fresh ripe fruits only.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chek Tuk</td>
<td>Occasionally used as feed</td>
<td>Good wrapping material</td>
<td>Occasionally used as cooked recipe</td>
<td>Have strong aroma, but very soft consistency. Not very popular.</td>
</tr>
<tr>
<td>Chek Snap Muok</td>
<td></td>
<td></td>
<td></td>
<td>Ripe banana is boiled</td>
</tr>
<tr>
<td>Chek Muoy Roy Snit</td>
<td></td>
<td></td>
<td></td>
<td>There are many small hands on a long bunch. The fruits are not eaten and have no economic value.</td>
</tr>
<tr>
<td>Chek Chvea</td>
<td>Occasionally used as feed</td>
<td>Good wrapping material</td>
<td>Occasionally used as cooked recipe</td>
<td>Because the ripe fruits can be full of seeds, only young green fruits are used. It is fermented.</td>
</tr>
<tr>
<td>Chek Meas</td>
<td></td>
<td></td>
<td></td>
<td>Used mainly for decoration</td>
</tr>
</tbody>
</table>
Production practices

The use of suckers as seed stock is the main practice in Cambodia. To a lesser extent, for planting a new crop, the use of rhizome is also practised. Normally, for the new plantation, suckers separated from the main stem are planted in a prepared pit. Commonly, suckers with three to four leaves are used. Cow manure and/or compost is mixed with the soil for filling the pit. Distance between pits is 2.5 x 4 meters or 3 x 4 meters. Two to three cycles of generation are kept before a new crop is established. Due to this practice, the spread of diseases such as fusarium wilt is difficult to control and/or eliminate and the yield becomes poorer from one cycle to the next. It is also possible that some pest populations can build up over the years.

Environmental factors

- **Water.** Water is the major environmental constraint to the production of banana. Rain in most cases provides the sole source of water available to the crop. Rainfall is variable in its amount and distribution, so much so, it can substantially affect the productivity of the crop. Floods may occur with excessive rain, and can cause massive decline in production, yield and quality.

- **Wind.** Damage to the stem and leaves caused by wind can also be observed very frequently when there is a storm.

Others

- **Research and development.** Because of resources constraint, public investment in agricultural research constitutes only a small portion of the total government budget. Needed infrastructure is not present and there is a big shortage of manpower in agricultural research. Presently, the Cambodian Agricultural Research and Development Institute (CARDI) is the first and only agricultural research institute in the country where a significant mass of researchers are employed.

Current banana R&D activities

At present, there are no R&D activities in any of the areas below:
- Germplasm collection/conservation
- Nutrition
- Irrigation
- Plant protection
- Production systems
- Postharvest
Opportunities and thrusts

As mentioned earlier, Cambodia is rich in genetic diversity of the *Musa* species. The need for their collection and conservation therefore requires special attention. The level of banana consumption in the country is high, thus increasing the production level is regarded as a major role in the policy guideline of the Royal Government of Cambodia in alleviating poverty in the country. In this regard, varietal improvement of banana and protection measures from major pests and diseases are very urgent issues.

Areas for future collaboration

- Germplasm collection and conservation
- Germplasm improvement
- Research support on every area including nutrition and water, plant protection, production systems, postharvest handling, etc.
- Human resource development program

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**Production and banana R&D in China**

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

**Banana industry status**

Banana is one of the most important fruits in China. The total area planted to banana is 259,000 hectares and among the fruits grown in China, it ranks seventh in terms of area. In 2001, the volume of production reached 5,393,000 tonnes and it ranked fourth next to apple, citrus and pear. Based on the worldwide statistics from FAO (2001), the production and planting area of China are fourth and fifth, respectively. In the last 20 years, the production of banana in China has been developed steadily, which contributed to China’s development.

Although some commercial plantations used to get yields as high as 60,000 kilograms per hectare in some years, the current average yield is 20,822 kilograms per hectare. This is due to typhoon and chilling. However, it is still the most productive fruit in China. The main consumption market is in the northern part of China. In 2000, China exported 50,248 tonnes, valued at US$33.05 million and at the same time, imported 593,533 tonnes, which is about US$169.3 million.

The major cultivar types planted are Xiangjiao (AAA, Cavendish), Fenjiao (ABB, Pisang Awak) and Dajiao (ABB, just like Bluggoe). Among Xiangjiao cultivars, Brazil Xiangjiao (a variety introduced from Brazil, like Valery) is the most popular. The others are Williams, Guangdong No. 2 and local cultivar Gaojiao Dundilei, etc.

**Production constraints**

**Major pests and diseases**

Yellow sigatoka (without black sigatoka) is the most common disease. Expensive chemicals (such as Tilt, Indar) are used to control it. Banana Bunchy Top Virus (BBTV) occurred in older field-plantings, but Cucumber Mosaic Virus (CMV) has become more serious than BBTV in new plantations due to popular adoption of tissue-cultured plants. The severe infection of Cavendish by *Fusarium oxysporum* f.sp. *cubense* (Foc) race 4 is found in some areas of Zhongshan and Panyu City with the tendency of fast spreading, and the control of it is still under study. In the last 2-3 years, the harm of banana leaves by an insect leaf

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roller (Prodenia litura Fabr.) is very common. The pseudostem borer (Odoiporus longicollis Olivier) also appears in old plantations. The banana root knot nematodes [Meloidogyne javanica (Treub) Chitwood], [M. arenaria (Neal) Chitwood], occurs in some sandy fields in Hainan and Fujian province, as well as other nematodes such as Rotylenchulus reniformis Linford & Oliveira.

Production practices

The commodity consciousness of farmers is not strong, which leads to bad fruit quality. But competing with imported banana, field dehanding and hand pruning are becoming popular. Seven to eight hands per bunch are recommended. Flower relicts are left and considered to help the finger grow longer. However, this makes the fruit more prone to postharvest diseases. Bunch protection is neglected sometimes causing too much finger scars. Because of wide range of plantation in China, no exact fruit age identification is recommended. The grower harvests the bunch just by experience although the date of flowering is marked.

Environmental factors

Most planting areas are suitable for banana growth. The quality of fruit is the best when harvested in December–May during the warmer winter, and some planting areas have been damaged by typhoon in summer and fall and sometimes by chilling in winter.

Current banana R&D activities, programmes and institutions involved

Germplasm

China is located in the north fringe of the world’s origin of banana especially Cavendish. Fruit-tree Research Institute of Guangdong Academy of Agricultural Sciences (GAAS) has carried out the collection of banana germplasm since 1950. In 1989, the National Fruit Tree Germplasm-Guangzhou Banana Field Gene Bank was set up, with the help of government funds of which the number of accessions was 210. At present, 170 accessions are conserved in the field and duplicated in vitro. The agronomic characters of most accessions have been appraised and recorded. Some of them are classified by isoperoxidase analyses. Recently, identification and classification of 35 banana varieties were studied based on AFLP analysis. The results showed that the 35 Musa AAA group Cavendish varieties could be divided into six subgroups, and three banana varieties (Jineiya, Pingguo and Yangjiangai) from different countries are actually the
same. The results based on the molecular level could provide theoretical basis for the classification of *Musa* AAA group Cavendish. At the same time, some rare and excellent germplasm has been applied and popularized in banana production, such as Fenjiao, Longyajiao, Gongjiao and so on.

**Nutrition and water**

Based on the study of nutritional requirement and the fertility investigation of different soil types, the research group headed by Soil Fertilizer Research Institute of GAAS, has worked out banana specific fertilizer through adjusting the ratio of N:P:K, and sometimes adding Mg, S, Ca and B element. It was proven that the banana specific fertilizer had larger application areas and better effects than ordinary compound fertilizer. Through treatment of balanced nutrition and good irrigation, the yield of banana per plant and per hectare has been improved remarkably; the maximum reaches to 95.5 kilograms and 75 tonnes, respectively. At present, water management is still a problem in the banana production, because water distribution is seasonal, summer and autumn are rainy seasons, but winter and spring are dry seasons. Modern irrigation system is little use in the banana plantations. Some farmers usually dig some deep wells and use pump for irrigation.

The study of vesicular-arbuscular mycorrhiza (VAM) on banana was done by Green Giant Environmental Biotechnology Limited by Dr Huang Jinxian. The results indicate that VAM plantlets grow faster, flowering and harvest earlier and have bigger fingers than the control.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of plants</th>
<th>Height (m)</th>
<th>Number of plants shoted before May</th>
<th>Shoted (%)</th>
<th>Bunch weight (kg)</th>
<th>Finger length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAM</td>
<td>291</td>
<td>2.25</td>
<td>245</td>
<td>84.2</td>
<td>29.5</td>
<td>27.3</td>
</tr>
<tr>
<td>Control</td>
<td>131</td>
<td>2.01</td>
<td>10</td>
<td>7.63</td>
<td>25.5</td>
<td>24.4</td>
</tr>
</tbody>
</table>

**Production systems**

The current production systems are mainly in smallholders; sale is separated from cultivation which leads to high cost and poor quality. Thus, intensive and industrial production systems must be established, such as banana production cooperative group with a famous trademark.

**Postharvest**

Recently, our technology and equipments of postharvest lagged behind
banana production. The equipment for harvest and package handling are rough, resulting to many scars and bruises on the fingers. Most of bananas are below B class.

**Opportunities and thrusts**

China became a member of WTO last year which provides many opportunities. Because we have wide places and appropriate climate for banana production, the redundant banana will have more markets than before. At the same time, the competence from overseas brings us big thrusts. The key is how to use biotechnology to breed new cultivars resistant to the diseases, extend the new technology, and improve the quality and efficiency of the production.

**Proposed areas of collaboration**

*Rapid propagation*

Tissue culture plant (TCP) is the most popular planting material in China. 80-90% of TCP are used for new plantations. Generally speaking, less than 3% off-type plants can be found in the field. More than 100 million TCP are planted every year. With the low price, it can be exported to other countries.

*Excellent germplasm exchange*

Germplasm exchange can screen some excellent cultivars and help produce some disease-resistant cultivars. Improve the banana industry in China through INIBAP collaboration.

*Harvest and postharvest management, technology and equipments*

*Marketing management*

These are the shortcomings of banana industry in China.
Status of banana industry in India

M.M. Mustaffa* and S. Sathiamoorthy

Introduction

Banana and plantain is one of the popular fruits in the world in terms of production and per capita consumption aside from being one of the important fruits of commerce. Banana and plantain is the fourth important global agricultural commodity after rice, wheat and maize in terms of gross value of production. It is cultivated in over a hundred countries throughout the tropical and subtropical regions of the world.

Banana in India

There has been a gradual increase in production of banana during the last 30 years and in the last decade, a spectacular growth has been witnessed due to the concerted efforts in banana research. The area has doubled from 200 000 hectares in early 1970s to 490 000 hectares in 2000 (Table 1). The banana production has made a giant leap by five times from 3.0 million tonnes in 1970s to 16.8 million tonnes in 2000. Productivity has also increased from 11.5 tonnes per hectare to 34.3 tonnes per hectare (national average), while in some states it is recorded as 60 tonnes per hectare. This significant increase in the production and productivity of banana happened due to adoption of improved cultivars, production technologies like optimum plant density; nutrition and water management coupled with integrated pest management strategies.

Table 1. Growth of banana industry in India.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>% Increase</th>
<th>Production (t)</th>
<th>% Increase</th>
<th>Productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td>2.0</td>
<td>---</td>
<td>2.6</td>
<td>---</td>
<td>11.5</td>
</tr>
<tr>
<td>1977</td>
<td>2.4</td>
<td>48.0</td>
<td>5.9</td>
<td>153.4</td>
<td>15.54</td>
</tr>
<tr>
<td>1987</td>
<td>3.0</td>
<td>150.0</td>
<td>8.9</td>
<td>255.0</td>
<td>17.42</td>
</tr>
<tr>
<td>1993</td>
<td>4.3</td>
<td>215.0</td>
<td>11.9</td>
<td>457.0</td>
<td>27.57</td>
</tr>
<tr>
<td>1997</td>
<td>4.4</td>
<td>220.0</td>
<td>13.33</td>
<td>512.0</td>
<td>29.7</td>
</tr>
<tr>
<td>2000</td>
<td>4.9</td>
<td>245.0</td>
<td>16.81</td>
<td>696.0</td>
<td>34.3</td>
</tr>
</tbody>
</table>

Although banana prefers tropical climate, it is well adapted to humid tropics, humid subtropics and semi arid subtropics and from the sea level up to an elevation of 2000 meters above mean sea level. Major

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growing states are: Tamil Nadu, Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa and West Bengal. Other states have limited area and production. Among the states, highest productivity is recorded in Maharashtra followed by Tamil Nadu (Table 2).

Table 2. Area, production and productivity of banana in India (2000).

<table>
<thead>
<tr>
<th>States</th>
<th>Area (ha)</th>
<th>Production (t)</th>
<th>Productivity (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamil Nadu</td>
<td>92 158</td>
<td>4 856 416</td>
<td>52.70</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>72 175</td>
<td>4 330 500</td>
<td>60.00</td>
</tr>
<tr>
<td>Karnataka</td>
<td>61 031</td>
<td>2 015 013</td>
<td>33.02</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>48 500</td>
<td>1 212 500</td>
<td>25.00</td>
</tr>
<tr>
<td>Assam</td>
<td>41 922</td>
<td>583 383</td>
<td>13.92</td>
</tr>
<tr>
<td>Gujarat</td>
<td>34 201</td>
<td>1 109 069</td>
<td>32.43</td>
</tr>
<tr>
<td>Bihar</td>
<td>29 196</td>
<td>583 920</td>
<td>20.00</td>
</tr>
<tr>
<td>Kerala</td>
<td>27 914</td>
<td>393 720</td>
<td>14.10</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>23 860</td>
<td>965 375</td>
<td>40.46</td>
</tr>
<tr>
<td>West Bengal</td>
<td>18 810</td>
<td>331 400</td>
<td>17.62</td>
</tr>
<tr>
<td>Orissa</td>
<td>16 350</td>
<td>193 540</td>
<td>11.84</td>
</tr>
<tr>
<td>Tripura</td>
<td>4 033</td>
<td>27 400</td>
<td>6.79</td>
</tr>
<tr>
<td>Others</td>
<td>20 278</td>
<td>209 922</td>
<td>10.35</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>490 428</strong></td>
<td><strong>6 812 158</strong></td>
<td><strong>34.28</strong></td>
</tr>
</tbody>
</table>


**Major commercial cultivars**

India is home to a wide range of *Musa* cultivars with varying genomic status and is endowed with diverse agro-climatic conditions, which has encouraged the development and sustenance of a large number of varieties catering to local needs. Though more than 20 varieties have assumed the status of commercial cultivation, Cavendish groups form the mainstay of Indian banana industry, owing to its high yield, wider market acceptability, shorter crop duration and high economic returns per unit area. Table 3 shows the important cultivars in India with their areas of production. Poovan is another cultivar grown commercially in different regions for its wider adaptability and tolerance to drought and diseases. Rasthali is grown in some specific regions due to its premium market price. Ney Poovan is also grown commercially in many parts of the country. Virupakshi, Monthan, Karpuravalli and Chakkia are also important in some states. Nendran is especially grown in Kerala and Tamil Nadu due to the local preference. The varietal situation prevailing in different states/regions indicates the regional adaptation, sustainability and regional preferences.
Gandevi, a mutant of Giant Cavendish has exhibited its superiority with an average yield of 45 kg bunch as compared to other Cavendish selections namely, Shrimanti, Padarse, etc.

A promising selection was made from Karpuravalli at NRCB, which is under multilocation trials. The selection is with 16 to 18 hands and produces 35 to 45 kg bunch with uniform sized fingers having better shelf life.

**Promising hybrids**

In India, earlier efforts have been made by Tamil Nadu Agricultural University (TNAU), Coimbatore but were successful in a very limited scale, in breeding AAB Prata dessert bananas (Pome type). Diploid male parents breeding at TNAU as potential sources of resistance to *Mycosphaerella* spp.; *Fusarium oxysporum* f.sp. *cubense* (Foc) and nematodes has resulted in development of 25 useful lines. Later, breeding work was also initiated at Banana Research Station, Kannara and Kerala Agricultural University, Thrissur.
Co-1

It is a promising Pome hybrid resulting from 3-way sequential crosses. It produces the typical acid/apple flavour of Virupakshi even in plains, contrary to Virupakshi, which develops aroma only when grown at higher altitudes.

H 1 (Agniswar x Pisang Lilin)

A shorter cropping cycle hybrid with resistance to leaf spot, fusarium wilt and burrowing nematode (*Radopholus similis*). It is a medium to tall plant, with a bunch weight of 14-16 kg. Elongated fruits turn attractive golden yellow upon ripening. It has a slightly acidic fruit and on full ripening, it develops high sugar content. H 1 has a remarkable early ratooning ability, completing 4 crop cycles in 3 years. This hybrid is immune to sigatoka leaf spot diseases.

H 2 (Vannan x Pisang Lilin)

A hybrid developed at Kerala Agricultural University (KAU), Kannara, is a medium-stature plant of 7-8 ft in height. Crop cycle is short with bunch coming to harvest in 11-12 months. Average weight of the bunch is 15-20 kg with short, stout, dark green Poovan-like fruits, which are arranged very compactly. Fruits are slightly acidic with pleasant sweet sour aroma. It is highly tolerant to leaf-spot disease and nematodes, hence, suitable for subsistence cultivation.

Uses

Bananas and plantains have high carbohydrate and low fat contents, making them useful particularly in low-fat diets. They are also good sources of many vitamins and minerals particularly vitamin A (carotene), vitamin B (thiamin, niacin and riboflavin), B₆ and vitamin C (ascorbic acid). Banana is low in sodium, making it a salt-free food. Due to the low lipid and higher energy value, bananas are recommended for obese and geriatric patients. Banana fruits, being rich in vitamin A, act as an aid to digestion. Boiled, mashed fruits are good for relieving constipation. The juice from the male bud provides remedy for stomach problems. Bananas are often used as the first solid food fed to infants in many parts of the globe, as they are readily acceptable and easily digestible.

Dried banana leaves are used as fuel in the rural areas of India. The dried sheaths are tightly twisted and made into two feet long sticks. In addition, dried banana leaves are used for thatching the roofs and also as a fence, which prevents the sun radiation and reduces the
pollution, it is popular in banana growing villages. Recently, use of
dried banana leaves has been reported as a better substrate to grow
oyster mushrooms than paddy straw.

All parts of the plant are useful. Paper board, tissue paper, etc., can be
prepared out of banana pseudostem. Various products like banana
chips, banana fig, ready to serve drink, flour and powder, jam,
confections, dehydration of core slices, wine, pickles from male bud,
immature fruit and stem, etc., can be made. Half of the bananas of the
world are eaten as cooked vegetable.

Banana fibre extracted from pseudostem waste has great scope in the
preparation of products like marine cordages, high quality paper
cardboards, tea bags, string thread, high quality fabric material and
paper for currency notes. Banana fibre being a natural sorbent has
high potential in absorbing the spilled oils in the refineries.

**Production constraints**

*Production practices*

- **Availability of disease-free planting materials**
  In India, banana is mostly propagated by suckers and to a smaller
  extent, by tissue culture. Due to the repeated replanting of the
  suckers from the infected areas, the banana industry is under threat
due to low yield, increased cost of cultivation and low income due
to higher incidence of diseases. The recent identification of new virus
diseases due to the Banana Streak Virus (BSV) and Banana Bract
Mosaic Virus (BBrMV) in banana has threatened the banana
industry. This situation has forced the farmers to search for disease-
free planting materials, which is highly essential for successful
banana production.

- **Clump spacing, management and root health**
  The adoption of annual planting in most parts of banana growing
  states has lead to increased unit cost of banana production in contrast
to the perennial cultivation adopted in other parts of the globe. In
  the annual planting system, clump management is vital to get
  maximum production with minimum cost of cultivation. Management of root health is most important for better absorption
  of nutrients and water for better growth and yield in clump
  management.

- **Integrated nutrient and water management**
  Banana is a heavy feeder and requires heavy fertilization of nitrogen
  and potassium. For cost minimization, optimum application of
fertilizers plays an important role in the production of banana. In addition, optimum application of water during the critical stages of plant growth plays a vital role in maximizing the production. In addition, to improve the soil health and sustainability, application of bio-fertilizers and organic manures to reduce the soil and water pollution has attracted attention.

- Better handling and storage of fruits
In India, an estimated loss of 25 to 30% accounting to Rs13 million (US$272 393) recorded every year due to poor handling, transportation and storage. Improved banana handling systems for better postharvest quality of fruits is necessary.

There is a need to use biotechnological approaches to increase the shelf-life of banana, as fruits are highly perishable in nature.

- Export of banana and plantains
Though India is the number one in banana production, the quantity of export of banana is negligible and accounts not even 0.1% of the world trade. Even though India is endowed with production of different cultivars and available throughout the year, it could not enter into the world trade due to the high cost of production and high quality standards of banana fruits for export market. This necessitates development of a technology exclusively for export market with appropriate production, harvesting, packing and storage.

Protection constraints

- Major pests
The major insect pests of banana in India are shown in Table 4.

<table>
<thead>
<tr>
<th>Pests</th>
<th>Distribution</th>
<th>Susceptible cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corm weevil (Cosmopolites sordidus)</td>
<td>Kerala, Maharashtra, Bihar, Assam, Andhra Pradesh, Arunachal Pradesh, Tamil Nadu</td>
<td>Nendran, Thellachakkarakeli, Poovan and Malbhog</td>
</tr>
<tr>
<td>Pseudostem borer (Odoiporus longicollis)</td>
<td>Andhra Pradesh, Bihar, Assam, Karnataka, Kerala, Arunachal Pradesh, Tamil Nadu</td>
<td>Nendran, Monthan, Dwarf Cavendish, Kunnan and Poovan</td>
</tr>
<tr>
<td>Scarring beetle (Besilepta subcostatum)</td>
<td>Bihar, Assam West Bengal</td>
<td>Chenichampa, Amritsagar and Malbhog</td>
</tr>
<tr>
<td>Aphids (Pentalonia nigronervosa)</td>
<td>Kerala, Tamil Nadu, Karnataka</td>
<td>Hill bananas, Red banana, Nendran and Poovan</td>
</tr>
<tr>
<td>Thrips (Thrips florum)</td>
<td>All banana growing regions</td>
<td>Cavendish, Plantain Silk and Monthan</td>
</tr>
</tbody>
</table>
• Nematodes
Table 5 shows the common banana nematodes in India, their distribution and susceptible cultivars.

**Table 5. Common banana nematodes.**

<table>
<thead>
<tr>
<th>Nematodes</th>
<th>Distribution</th>
<th>Susceptible cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root- knot nematode (*)</td>
<td>Tamil Nadu, Assam, Bihar, Andhra Pradesh, Karnataka</td>
<td>All cultivars</td>
</tr>
<tr>
<td>Burrowing nematode (*)</td>
<td>Kerala, Bihar, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu</td>
<td>Robusta, Nendran, Poovan, Rasthali, Pachanadan and Karpuravalli</td>
</tr>
<tr>
<td>Root lesion nematode (**)</td>
<td>Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Gujarath</td>
<td>Almost all the commercial cultivars except Nendran is highly susceptible</td>
</tr>
<tr>
<td>Spiral nematode (*)</td>
<td>Kerala, Assam, Maharashtra, Bihar, Tamil Nadu</td>
<td>Almost all commercial cultivars</td>
</tr>
<tr>
<td>Cyst nematode (*)</td>
<td>Kerala, Karnataka, Tamil Nadu, Assam</td>
<td>-</td>
</tr>
</tbody>
</table>

• Major diseases
The major diseases of banana and susceptible cultivars are shown in Table 6.

**Table 6. Major diseases of banana.**

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Susceptible cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fungus</strong></td>
<td></td>
</tr>
<tr>
<td>Yellow sigatoka</td>
<td>Cavendish, Red banana, Rasthali, Nendran, Pome types</td>
</tr>
<tr>
<td>Black sigatoka</td>
<td>Rasthali, Karpuravalli, Red banana, Pome types for race 1 and ABB cooking bananas for race 2</td>
</tr>
<tr>
<td>Fusarium wilt (races 1 and 2)</td>
<td>Rasthali, Karpuravalli, Red banana, Pome types for race 1 and ABB cooking bananas for race 2</td>
</tr>
<tr>
<td><strong>Bacterial</strong></td>
<td></td>
</tr>
<tr>
<td>Head rot (<em>Erwinia carotovora</em>)</td>
<td>Cavendish clones and Nendran (French plantains)</td>
</tr>
<tr>
<td><strong>Virus</strong></td>
<td></td>
</tr>
<tr>
<td>Bunchy top</td>
<td>All the clones</td>
</tr>
<tr>
<td>Infectious chlorosis (CMV)</td>
<td>Cavendish clones, Poovan (Mysore), Red banana, Pome</td>
</tr>
<tr>
<td>Banana streak virus (BSV)</td>
<td>Matti, Cavendish clones, Poovan, Virupakshi</td>
</tr>
<tr>
<td>Banana bract mosaic virus (BBrMV)</td>
<td>Cavendish clones, Pisang Awak, Nendran, Monthan, Pome types, Poovan, Red banana and many ABB clones</td>
</tr>
</tbody>
</table>
• Maladies of unknown etiology

Table 7. Maladies of unknown etiology on banana.

<table>
<thead>
<tr>
<th>Malady</th>
<th>Symptoms</th>
<th>Susceptible cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neervazhai</td>
<td>Immature unfilled fingers, robust plant stature</td>
<td>Nendran (Plantain)</td>
</tr>
<tr>
<td>Kottavazhai (seediness)</td>
<td>Fruits remain immature, dark green in colour and contain conspicuous seed-like enlarged ovules</td>
<td>Poovan (Mysore)</td>
</tr>
</tbody>
</table>

Environmental factors

• Problem soils
Salt accumulation in root zone causes saline and alkaline soils. The higher accumulation of sodium in alkaline soil causes reduced cation, especially potassium, uptake and also causes injury to roots causing leaf injury, thereby decreasing yield.

• Wind
With high velocity, wind causes blow-downs in tropical banana plantations. At a wind velocity of more than 20 meters/second, between 50-100% of the plants can be blown down. Apart from this, regular strong winds cause leaf tearing which reduces productivity significantly. Winds between 2.5 to 5 meters/second can reduce fruit quality by enhancing leaf and dust abrasion.

• High temperature
The important problems encountered due to hot weather are summer leaf stress mixed-ripe fruits and ripe fruit breakdown.

• Drought
Periodical occurrence of drought leads to yield reduction, caused by a physiological reduction of assimilation. Prolonged drought produces small, stunted plants, reduced leaf emergence, choked bunches and small bunches with shrivelled, blackened fingers.

Others

• Postharvest technology
Handling damages in banana could occur during harvesting, handling, collection, transport, loading onto trucks, off-loading, handling by the wholesalers, retailers and finally by consumers. The physiological loss in weight, finger drop, impact damage due to rough handling and spoilages are the main reasons for the losses
during postharvest handling of banana. About 8-9% losses are recorded at farmers’ level, while 20-25% at wholesalers and 15% at retailers level (Table 8).

**Table 8.** Losses during different stages of marketing and transportation of banana.

<table>
<thead>
<tr>
<th>Stage of marketing</th>
<th>Transported by</th>
<th>Mode of transport and losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>From field to the</td>
<td>Farmer or preharvest contractor</td>
<td>Head loads (8-10%), bullock cart and handcart (60-62%), camel cart (2-3%), tractors (20-25%), cycle trolleys (1-3%)</td>
</tr>
<tr>
<td>village market or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>primary wholesale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>market</td>
<td></td>
<td></td>
</tr>
<tr>
<td>From village market</td>
<td>Commission agents</td>
<td>Trucks (25%), lorries (30%), railway wagons (30%), bullock and handcart (15%)</td>
</tr>
<tr>
<td>or primary wholesale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>market to secondary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wholesale market</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary wholesale</td>
<td>Retailer or consumer</td>
<td>Head loads, bicycles, market hand carts, camel or bullock carts</td>
</tr>
<tr>
<td>to consumer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**R&D activities and programmes on banana in India**

All India Coordinated Research Project (AICRP) which was started in 1971 with four centers, has expanded to ten centers covering major banana growing regions. By the year 2020, 25 million tonnes of banana would be required to feed the increasing population and to meet the export needs, which have to be produced from the limited land and water resources. Thus, to meet the challenges, National Research Centre on Banana (NRCB) was established and started functioning from April 1994 with a mission to enhance the production and productivity of banana.

**National Research Centre for Banana, Tiruchirapalli, India**

The major areas of research are: germplasm management, improvement of banana, biotechnology, production technology, postharvest technology, crop protection and physiology and biochemistry.

List of on-going research programmes

- **Crop improvement**
  1. Management of genetic resources of banana
  2. Improvement through conventional breeding of banana
• Crop production and postharvest technology
  1. Standardization of agro-techniques for banana production and productivity
  2. Standardization of technology for organic banana production
  3. Studies on amendments and reclamation of saline sodic soil for banana
  4. Integrated nutrient management in banana
  5. Micronutrients in banana
  6. Studies on handling, storage and processing of banana

• Crop protection
  1. Insect pest management in banana
  2. Studies on banana nematodes and their management
  3. Studies on fungal and bacterial diseases and their management
  4. Biocontrol of fusarium wilt of banana
  5. Studies on viral diseases of banana and their management

• Crop physiology and biochemistry
  1. Studies on physiology aspects of flowering and fruit development in banana
  2. Biochemical and physiological studies on maladies of unknown etiology

Opportunities and thrust

India has a vast network of banana research programmes. NRCB plays an active role in banana research. In addition, various SAUs working on banana research and various ICAR centres are also involved in various aspects of banana research. NRCB is actively collaborating with various national and international agencies in banana research through which mutual benefit can be obtained.

Opportunities

There are several opportunities in banana germplasm and breeding. India being one of the centers of biodiversity of banana is endowed with more than eight wild species and 120 distinct clones. Being at the center of origin for *M. balbisiana*, which is a source of resistance for biotic and abiotic stresses, the coevolution of pathogen along with the genomes could be identified in the center of origin. Thus, exploration of this center of origin could help in identification of resistance sources for important diseases of banana.

India is the only country where different varieties/cultivars are grown in a large area, where there could be a possibility of useful mutations/
point mutations, which could be of importance for disease resistance, quality, bunch characters, etc. Survey of these areas for selecting superior clonal selection is essential to locate such variability existing in nature.

Different system of cultivation is followed in India ranging from household backyard gardening, small marginal holding to large contract farming. The expertise could be useful for other countries where similar type of cultivation is practised.

Nutritional requirement in relation to high density of planting is another aspect of research that deserves attention. More efforts would be needed for efficient water management and fertigation requirement for banana.

Research on hormone-impregnated foliar nutrient sprays deserves attention as pre- and postharvest application. The physiology of sex change in banana is yet to be understood clearly. The involvement of hormones in this aspect would greatly benefit in improving the grade of bunch and timing of fertilizer treatments.

Postharvest technology and processing helps the farmers to tide over the glut situation and the technology could help in exporting bananas to distant markets due to the availability of fruits during off-season.

**Future thrusts**

- Identification of areas of natural diversity and collection through prospection and exotic introduction. Conservation and characterization of *Musa* germplasm by *in situ* and *ex situ* strategies has to be developed.
- Evaluation of germplasm for their useful characters and resistance to biotic and abiotic stresses.
- Study on genomics and proteomics of Indian banana.
- Use of bio-technological tools for widening the genetic base of banana.
- Identification of resistance sources for major biotic stresses.
- Development of production technology for export banana.
- Study on the clump management and root health.
- Study on organic banana production.
- Efficient management of nutrients and water.
- Molecular approaches for the management of major nematode pathogens in banana.
- Characterization of fusarium wilt pathogen isolates of different regions of India to identify the variability and preparation of VCG maps of India.
- Development of transgenic banana plants by introducing PR-proteins genes against fusarium of banana.
- Molecular diagnostic tools for banana viruses.
- Pathogen derived resistance – a molecular approach for control of viruses.
- Tools to develop transgenic banana resistant to BBMV and BBTV.
- Induced resistance through PGPR and other chemicals.

**Proposed areas of collaborations**

- **Breeding**
  - Molecular characterization of *Musa* germplasm and study of genetic diversity using chloroplast markers
  - Development of PCR based markers for A and B genomes
  - Joint collaborative exploration programmes in other centers of diversity in Southeast Asian region and documentation of *Musa* diversity in Asia

- **Production technology**
  - Nutrient management
  - Fertigation
  - Organic farming
  - Export of banana
  - Physiology of flowering

- **Postharvest technology**
  - Controlled atmosphere storage of banana
  - Development of new kinds of value-added products from banana and its wastes

- **Nematology**
  - Isolation of toxic principles in botanicals for the management of banana nematodes
  - Molecular approaches for the management of banana nematodes
  - Development of transgenic banana against major banana nematodes

- **Virology**
  - Developing transgenic plants resistance to virus diseases
  - Detection and characterization of BSV integral in infected germplasm
  - Strain differentiation in BBrMV
  - Strain differentiation in BBTV
Current status of banana R&D in Indonesia

I. Dja* and Agus Sutanto

Introduction

Banana contributed 51% of 6,661,761 tonnes of Indonesian fruit production (Anonym. 2000). The area of productions are scattered throughout the country with various agro-ecosystem and cultivation system. The major production areas are West Java, East Java, Central Java, South Sulawesi, West Sumatera, and others, which produce 40%, 19%, 13%, 4% and 24%, respectively (Anonym 2000). The largest area of banana production is in Java (61%) and followed by Sumatera (16%), Sulawesi (8%), Kalimantan (4%) and other islands (Anonym. 2000). Major commercial dessert cultivars are Pisang Ambon Kuning, P. Ambon Hijau, P. Barangan, P. Raja Serai, P. Emas and P. Berlin, and cooking bananas/plantains are P. Kepok, P. Raja Bulu, P. Oli/Jantan, P. Tanduk and P. Candi.

Commonly, bananas are grown by smallholders with minimum cultivation and production inputs. In some areas, smallholders cultivate banana with monoculture system and mix-cropping system. Their productions are generally for local market, banana chips and dry banana industry (P. Sale). A few commercial growers at Lampung (Sumatera), Halmahera (Maluku) and Mojokerto (East Java) have established large plantation mainly for export and industry of banana flour and puree.

Although banana production has increased over the years, the production area of banana has declined from 1997 to 1999 (Table 1), particularly in the central area of banana production such as Sumatera, Sulawesi, Central and East Java. The declining areas were caused by the outbreak of several pests and diseases such as panama disease, blood disease, moko disease, sigatoka, BBTV, CMV, borer and nematodes. The major diseases in the central area of banana production are panama disease (fusarium wilt), blood disease and moko disease (bacterial wilt disease). Export of banana was significantly increased from 1992 to 1993 and from 1995 to 1996 (Table 1), because private sectors have involved on banana agribusiness. Banana export decreased from 1996 until 1999 due to the outbreak of some banana diseases on the commercial banana plantations, insufficient supply of
Fusarium wilt and bacterial wilt diseases of banana (BDB and Moko) are the most important diseases in Indonesia. These diseases have infected banana plantations in almost all central areas of banana production in Indonesia. Most of commercial dessert varieties such as Barangan, Ambon Hijau, Ambon Kuning, Raja Serai are susceptible to fusarium wilt. There is a lack of information on the outbreak of the diseases except for fusarium wilt. In north Sumatera, where the main cultivar is P. Barangan, 22% was found in Simalungun, and 25% was found in Deli Serdang (CRIH 1994). P. Ambon Kuning, P. Ambon Hijau, P. Tanduk in Java, Bali and Nusatenggara, P. Raja Serai and P. Buai in West Sumatera, Cavendish in Lampung and Riau are destroyed by fusarium wilt.

Bacterial wilt diseases (BDB and moko disease) had been reported becoming endemic in almost islands of Indonesia (Muharam and Subiyanto 1991; Sahlan and Nurhadi 1994; Hermanto et al. 1998) and had also caused some significant economic losses in the endemic area and effects on the farmers’ social life. In South Sulawesi, 70-80% of banana plantation was destroyed (Roesmiyanto and Hutagalung 1989) and 27-36% in West Java (Muharam and Subijanto 1991). The province of Lampung lost more than 20.000 tonnes of banana valued at US$1 million (Nurhadi et al. 1994). Based on the laboratory testing, there are no resistant varieties to BDB (Baharuddin 1994), but several reports shown that BDB mainly affected some cooking bananas such as P. Kepok, P. Kapas, P. Nangka, P. Raja and P. Dewaka (Edison et al. 1996; Setyobudi and Hermanto 1999).

Weevil borer is one of the important pests on banana and plantain in some countries like Uganda and other African countries. In Indonesia, banana weevil borer is found from lowland to highland. Under field conditions in West Sumatera, AAB groups of *Musa* were susceptible to banana weevil, while AA groups were relatively resistant with little damage and limited penetration into the corm (Hasyim et al. 1997).

**Table 1. Area, production and export of banana in Indonesia (1991-1999).**

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (ha)</th>
<th>Production (tonnes)</th>
<th>Export (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>76,721</td>
<td>2,650,814</td>
<td>11</td>
</tr>
<tr>
<td>1993</td>
<td>70,721</td>
<td>2,643,812</td>
<td>24,917</td>
</tr>
<tr>
<td>1994</td>
<td>50,041</td>
<td>3,086,557</td>
<td>33,092</td>
</tr>
<tr>
<td>1995</td>
<td>49,044</td>
<td>3,805,431</td>
<td>55,318</td>
</tr>
<tr>
<td>1996</td>
<td>48,944</td>
<td>3,023,431</td>
<td>101,495</td>
</tr>
<tr>
<td>1997</td>
<td>78,115</td>
<td>3,057,081</td>
<td>71,028</td>
</tr>
<tr>
<td>1998</td>
<td>71,537</td>
<td>3,176,749</td>
<td>76,982</td>
</tr>
<tr>
<td>1999</td>
<td>70,560</td>
<td>3,376,661</td>
<td>76,726</td>
</tr>
</tbody>
</table>

Source: Central Bureau of Statistics and Directorate General Production of Horticulture and Various Plants.

**Major banana diseases and pests in Indonesia**
**Current Banana Researches at Solok Research Institute of Fruits (RIF)**

*Musa germplasm collection and conservation*

Solok RIF has done banana-collecting missions since 1994, but some of the collections were affected by fusarium wilt and recollected again. Currently, there are 200 accessions which are maintained in the field, screenhouse and *in vitro* laboratory. Under the collaboration with INIBAP, *Musa* collecting missions were carried out in Maluku Islands in 1996 and Papua (Irian Jaya) in 2002 and obtained 28 and 70 accessions, respectively. A unique accession obtained from Seram Island (Central Maluku) was *P. Sepatu Amora*. This variety is similar to Kepok (ABB/BBB), but no male bud flower. In appropriate condition, *P. Sepatu Amora* produces up to 18 hands per bunch. Due to the absence of male bud flower, this variety has potential to escape from vector of BDB. In Papua, many of accessions were AA-types, similar to those from Papua New Guinea. There are two accessions found in Papua as well as in Maluku; *P. Dawaka* and *P. Jarum*. *P. Dawaka* is similar to *P. Kepok*, but the size of the fruit is bigger and fruit shape is similar to Bluggoe. *P. Jarum*, with the hairy pedicel, is the most popular dessert banana in Maluku Island. *Musa schizocarpa*, *M. lolodensis* and *M. acuminata banksii* were found during the exploration in Papua.

Banana-collecting missions were also done in Java and Sumatera Islands. Some wild types of *M. acuminata* were found in Sumatera, designed by BKT-11, BSK-30, SLK-29, and SPN-21. The first two accessions (BKT-11 and BSK-30) are potential for male parent, because those are resistant to fusarium wilt and bearing long size of bunch (18 to 20 hands). For banana improvement, these accessions are used as pollen sources and crossed with commercial varieties (research on going).

**Preparation of IMTP-III project**

Under the Letter of Agreement (LOA) with INIBAP 2001/22, CRIH received *in vitro* planting materials (21 accessions) from INIBAP Transit Centre. These accessions have been multiplied in the tissue culture laboratory of Research Institute for Ornamental Plants and Solok RIF. Three locations are chosen as the sites of experiments, where the presence of the pathogen is sufficient: RIF (West Sumatera), Berastagi
Research Station (North Sumatera), and Bogor University of Agriculture, West Java (tentative) or Nusantara Tropical Fruit, Lampung.

Some of the planting materials are being maintained in pots and ready for planting by the middle of October 2002.

**IPM on banana pests and diseases control**

Integrated pest management (IPM) can be defined as the use of multiple tactics in a compatible manner to maintain pest populations at levels below those causing economic injury while providing protection against hazards to humans, animals, plants and the environment (Frison 1998). IPM is thus ecologically based pest management that makes full use of natural and cultural processes and methods, including host resistance and biological control. There are some tactics that can be employed into IPM strategies, either alone or in combinations which include regulatory control, cultural control, host plant resistance, biological control and chemical control.

Most of banana pests and diseases such as weevil borer, fusarium wilt, BDB, Moko disease, sigatoka leaf spot and BBTV are difficult to be controlled by pesticides. IPM tactics that used by RIF for controlling such pests and diseases, particularly weevil borer, fusarium wilt and bacterial wilt, are regulatory control, cultural control, host plant resistance and biological control. Regulatory control by quarantine is applied in order to restrict the movement of pests into areas where they do not occur. Quarantine usually goes hand in hand with eradication. Cultural control is integral of farming practice. In banana, a practical disease management technology was developed successfully and adopted by farmers in the Philippines to manage ‘bugtok’, the same disease that also has been ravaging Saba (similar to Kepok). This technology was adopted to manage BDB in Sumatera (Setyobudi and Hermanto 1999). Some researches have been carried out in order to induce banana plant resistance to fusarium wilt and BDB through conventional hybridization between commercial variety and wild *Musa*, off-type induction using mutagen (EMS) and gamma radiation, and *in vitro* screening and selection of plantlets on pathogenic toxin medium (Karsinah *et al*. 1999; Djatnika *et al*. 2000). One promising variety named P. Sepatu Amora is not resistant to BDB, but avoidance variety due to the absence of male bud flower. This variety is now being multiplied to produce a sufficient amount of planting materials for further evaluation and dissemination. The use of natural pests to
reduce the impact of the 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*. In the laboratory test, those antagonistic microbes suppressed *F. oxysporum* f.sp. *cubense* colonies. The infected plant were significantly reduced when the suspension of *Pseudomonas fluorescens* strain MR 96 were poured to soil surrounding banana rhizosphere (Djatnika *et al.* 2001). Some natural enemies of banana weevil borer have been known, but the most promising predator is *Plasius javanicus*. Both the larvae and adults attack weevil larvae and eggs. The adults prefer to eat eggs, but the larvae prefer to kill banana weevil larvae.

**Collaboration and thrust**

In order to rehabilitate banana production in Indonesia, RIF will continue to collaborate with INIBAP and other international and regional institutions. Currently, CRIH collaborates with Australia through an ACIAR project on banana postharvest handling and marketing and the next phase on the subject of management of fusarium wilt control. Dissemination of banana bacterial wilt and fusarium wilt control to the decision maker and stakeholders will be held on Padang, West Sumatera due to the collaboration of RIF, Assessment Institute of Agricultural Technology (AIAT) and regional government.

**References**


Banana industry and R&D in Malaysia

Nik Mohd. Masdek Nik Hassan*

Banana industry status

Banana is one of the most widely grown and important fruit crops for Malaysia both for the domestic and export market. The importance of banana is clearly indicated in the Third National Agricultural Policy (1998–2010) where it is listed as one of the 15 fruit types prioritized for commercial cultivation.

In the past 10 years (1992–2001), the acreage of banana has somewhat stabilized at around 30 000 to 31 000 hectares (Table 1). This acreage amounts to about 10-12% of the total acreage for fruits. Of the total banana acreage, almost half is cultivated with Pisang Berangan and the Cavendish cultivars for both local consumption and export. The other half is planted with other local cultivars such as P. Mas, P. Rastali, P. Nangka, P. Raja, P. Awak, P. Abu and P. Tandok, mainly for the domestic market.

Table 1. Banana acreage, production, export volume and value of banana in Malaysia (1992 - 2001).

<table>
<thead>
<tr>
<th>Year</th>
<th>Acreage (ha)</th>
<th>Production (t)</th>
<th>Export (t)</th>
<th>Exports (000$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>28 700</td>
<td>510 000</td>
<td>18 695</td>
<td>3 519</td>
</tr>
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<td>31 046</td>
<td>540 000</td>
<td>31 814</td>
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</tr>
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<td>1994</td>
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<td>530 000</td>
<td>81 900</td>
<td>10 601</td>
</tr>
<tr>
<td>1995</td>
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<td>530 000</td>
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</tr>
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<td>2001</td>
<td>31 000</td>
<td>560 000</td>
<td>n.a.</td>
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</tr>
</tbody>
</table>

Source: FAO

Total production over the past 10 years ranges between 510 000 to 560 000 metric tonnes per year. Thus, Malaysia is a very small producer compared to the neighbouring countries such as Thailand (2 million tonnes), Philippines (4 million tonnes) and India (8 million tonnes). Malaysia exported a 10-year average of about 37 000 metric tonnes per year or 7% of its total production with an average value of US$7

*Research Officer, Horticulture Research Centre, MARDI, Serdang, Selangor, Malaysia.
million. The traditional markets for Malaysian bananas are Singapore, Hong Kong, Brunei and the Middle East.

The annual per capita consumption of banana is 5.5 kg for Malaysia and is very much lower than some European countries at more than 10 kg. The popular varieties for dessert are P. Mas (2.7 kg per annual capita consumption) followed by P. Rastali (0.70 kg) and P. Berangan (0.48 kg). For the cooking variety, P. Nangka is the most consumed followed by P. Abu and P. Raja perhaps due to ease of availability.

**Major cultivars of banana in Malaysia**

Malaysia is considered as one of the center of diversity of banana as evidenced by the diploids AA (eg. Pisang Mas, P. Jari Buaya, P. Lilin, etc.) and the natural hybrids of AAB (P. Nangka, P. Raja, P. Rastali, etc.) and ABB (P. Awak, P. Abu, P. Nipah, etc.). Thus, there exists a variety of choice for the farmers and growers (Table 2).

**Table 2. Agronomic characters of some common banana cultivars.**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Yield (kg/bunch)</th>
<th>Plant height (m)</th>
<th>Time to shooting (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavendish (Montel)</td>
<td>20 – 30</td>
<td>1.8 – 2.0</td>
<td>7 – 9</td>
</tr>
<tr>
<td>Pisang Mas</td>
<td>8 – 14</td>
<td>2.0 – 2.5</td>
<td>6 – 8</td>
</tr>
<tr>
<td>Pisang Berangan</td>
<td>12 – 20</td>
<td>2.0 – 3.0</td>
<td>7 – 9</td>
</tr>
<tr>
<td>Pisang Rastali</td>
<td>12 – 16</td>
<td>1.5 – 2.0</td>
<td>7 – 9</td>
</tr>
<tr>
<td>Pisang Tandok</td>
<td>10 – 15</td>
<td>3.0 – 3.8</td>
<td>8 – 10</td>
</tr>
<tr>
<td>Pisang Nangka</td>
<td>14 – 20</td>
<td>2.0 – 2.5</td>
<td>7 – 9</td>
</tr>
<tr>
<td>Pisang Raja</td>
<td>14 – 20</td>
<td>2.5 – 3.0</td>
<td>8 – 10</td>
</tr>
<tr>
<td>Pisang Awak</td>
<td>14 – 20</td>
<td>2.5 – 3.0</td>
<td>8 – 9</td>
</tr>
<tr>
<td>Pisang Kapas</td>
<td>15 – 25</td>
<td>1.5 – 2.0</td>
<td>7 – 9</td>
</tr>
<tr>
<td>Pisang Abu Nipah</td>
<td>15 – 25</td>
<td>2.8 – 3.5</td>
<td>9 – 11</td>
</tr>
</tbody>
</table>

The major or potential commercial cultivars in Malaysia are as follows:

**Cavendish banana.** This has been the cultivar known worldwide for international trade. Large scale commercial growers and other big operators have opted for the Cavendish banana to cater for the export market. Furthermore, this cultivar shows good plant vigour and higher yield compared to the local cultivars. This cultivar was also selected based on their resistance to Fusarium oxysporum f.sp. cubense (Foc) race 1 and 2. However, with the appearance of race 4, this cultivar is facing new challenges from fusarium wilt disease.

**Pisang Berangan.** Presently, this is the most popular dessert banana grown in Malaysia due to consumer preference. It is also popular with the growers due to comparatively good yield and availability of
planting materials, and it is well accepted in traditional export markets. The cultivation of this cultivar is under tremendous pressure lately due to its susceptibility to fusarium wilt disease. Good management and production practices must be adopted to ensure a successful and profitable crop.

**Pisang Mas.** This diploid AA has a sweet and superior taste and exhibits a somewhat golden yellow colour of the skin and flesh. This variety is popular among the locals. However, the plant in moderately vigorous and yield is low. It comes to flowering early, and it is a smaller plant compared to the other cultivars; therefore a higher planting density can be adopted to counter low yield.

**Pisang Rastali.** This popular variety has a unique sweet-sour taste with very fine, smooth, milky white flesh. Unfortunately, this cultivar is also highly susceptible to fusarium wilt resulting in its limited availability in the market and the difficulty of getting sufficient planting materials.

The popular cooking/processing banana cultivars are as follows:

**Pisang Tandok.** This belongs to the plaintain group with large fingers, it is a tall plant, has longer time to shooting, yield is low to average (10-15 kg) and a preferred host to the banana weevil. This is also the most sought after cultivar for making banana chips.

**Pisang Nangka.** A very common cooking cultivar, hardy and easy to grow, comes to flowering early and gives good yield. It shows moderate tolerance to fusarium wilt.

**Pisang Raja.** This popular variety is superior in taste among the cooking/processed bananas and is also taken as dessert. It has a very sweet taste, with smooth texture. It also produces a moderate yield although time to flowering is slightly longer.

**Pisang Awak.** Popular in certain parts of the country, this has a fairly good yield and is moderately tolerant to fusarium wilt.

**Pisang Kapas.** This is the popular variety for processing into banana figs or smoked banana. It is quite a vigorous and early flowering.

**Pisang Abu Nipah.** This is the most hardy variety, it is a tall plant and takes the longest time to flower. The yield is moderate.
**Utilisation of banana**

Bananas are energy-rich in the form of starch and sugar and a rich source of vitamin A, C, B1, B2 and minerals. Most farmers grow the local clones both for dessert (usually fine-textured, sweet or sweet-sour taste) and cooking/processing (more starchy) purposes. Banana processing and product development is only a small cottage industry utilising simple machinery and packaging facilities. Various food, non-food products and other uses are listed below (Table 3).

**Table 3. Product utilisation of banana.**

<table>
<thead>
<tr>
<th>Plant parts</th>
<th>Products/Use</th>
<th>Recommended clones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peel</td>
<td>Pectin</td>
<td>Most clones</td>
</tr>
<tr>
<td>Fruit -ripe</td>
<td>Puree</td>
<td>P. Mas, Cavendish</td>
</tr>
<tr>
<td></td>
<td>Jam</td>
<td>P. Mas, P. Berangan</td>
</tr>
<tr>
<td></td>
<td>Crisps</td>
<td>P. Berangan, P. Mas</td>
</tr>
<tr>
<td></td>
<td>Drinks</td>
<td>P. Mas</td>
</tr>
<tr>
<td></td>
<td>Vinegar</td>
<td>P. Mas</td>
</tr>
<tr>
<td></td>
<td>Fig</td>
<td>P. Kadas, P. Mas, P. Berangan</td>
</tr>
<tr>
<td></td>
<td>Candy/Confectionary</td>
<td>P. Mas, P. Berangan</td>
</tr>
<tr>
<td>Fruit -mature</td>
<td>Chips</td>
<td>P. Tandok, P. Gading, P. Nangka</td>
</tr>
<tr>
<td></td>
<td>Powder</td>
<td>P. Raja, P. Mas, P. Berangan</td>
</tr>
<tr>
<td>Leaves</td>
<td>Wrapper (local delicacies)</td>
<td>Wild banana</td>
</tr>
<tr>
<td></td>
<td>Mulching</td>
<td>All types</td>
</tr>
<tr>
<td>Male bud</td>
<td>Vegetable</td>
<td>P. Berangan, Others</td>
</tr>
<tr>
<td>Pseudostems</td>
<td>Mulching</td>
<td>All types</td>
</tr>
</tbody>
</table>

**Production constraints**

The destruction due to pests and diseases, the production system, high cost of production and transportation, low yield, competition from neighbouring countries and from other fruit types within the country are constraints and weaknesses in the production of banana.

**Pests and diseases**

The major pests are banana weevil (*Cosmopolites sordidus*), leaf roller (*Erionata thrax*) and nematodes. Thrips, aphids, spider mites and scab moth are minor pests, which do not cause serious damage. The banana weevil is frequently associated with P. Tandok and other cultivars damaging the corms and pseudostems. This results in stunted growth, weak plant base, yellowing of leaves and rotting of the corms.

Leaf rollers cause seasonal damage and are normally controlled by natural predators. Nematodes played an important roles in reducing banana production. There are 14 nematode species associated with banana but 8 species in 4 genera are considered as potentially of
economic importance based on plant growth, damage on corms and roots of banana in the field. The nematode species are as follows: *Radopholus similis*, *Pratylenchus coffeae*, *P. brachyurus*, *Meloidogyne incognita*, *M. javanica*, *Helicotylenchus dihystera*, *H. multitinctus* and *H. pasohi*.

Diseases are the major constraints to banana production. Topping the list is panama disease or fusarium wilt caused by the soil-borne pathogen Foc. Foc race 1, 2 and the aggressive and destructive race 4 are present. *P. Berangan*, *P. Rastali* and the Cavendish group are very susceptible. Other dessert varieties are moderately susceptible. The cooking varieties are more tolerant.

The second most damaging diseases are yellow sigatoka and black leaf streak disease/black sigatoka caused by *Mycosphaerella musicola* and *M. fijiensis*, respectively. Another leaf disease, which has been recorded and reported to have symptoms indistinguishable from the two previous leaf spots, is *M. eumusae* (Anamorph: *Septoria eumusae*). These diseases infect young leaves which become necrotic, with reduced photosynthetic leaf area, thus, reduces yield.

Cladosporium leaf speckle is another foliar disease especially serious on certain accessions of *P. Berangan*. Although other cultivars such as *P. Mas*, *P. Lemak Manis* and *P. Abu* can be infected, it is only of minor importance.

Leaf freckle caused by *Guignardia musae* (*Phyllostictina musarum*) is very serious especially on *P. Berangan* and to a certain extent on *P. Rastali*.

*Production practices*

The cultivation of banana is basically a smallholder enterprise with small farm size, unorganized and adoption of inferior technology. Very often, yield is low with inferior quality. There are only a few large-scale banana plantations utilising modern technology with good management practices. Normally, these farms are export-oriented. Another form of production system is mixed farming with plantation crop. Banana has been identified as a short-term cash crop that can be integrated with newly planted rubber trees, oil palm and other forest species. This practice is commonly adopted by largescale operators as well as smallholder to optimize labour usage and land utilization. However, prime land under fruit was lost to infrastructural development and development of new township. Relocation to marginal lands has resulted in higher input and lower return. In
addition, labour is getting scarce and becoming more expensive.

**Current R&D activities**

Research activities on banana are currently being conducted by research institutions (such as MARDI, MINT), universities (such as UPM, UM, USM, UKM) and private companies (United Plantations). The various aspects of research activities being undertaken are the following:

i)  Biotechnological methods for classification/genetic relationship of Malaysian banana varieties.

ii) Improvement of agronomic traits for commercial varieties. The main objective is to develop cultivars resistant or tolerant to fusarium wilt and improvement of yield. Various approaches will be adopted as follows: transformation method, somaclonal variation, use of biocontrol agent, use of rhizobacteria as biofertilizers and bioenhancers, and mutation induction.

iii) Foliar diseases.

iv) Processing of bananas.

v) Collection and conservation of cooking bananas.

**Proposed areas of collaboration**

As the Southeast Asian region is the center of diversity, there exists a pool of genetic resources that can be utilized to improve the commercial varieties especially in relation to yield improvement and resistance to various pests and diseases. However, shortcomings due to constraints of financial resources, knowledge and expertise in specific areas have delayed the expected progress. Thus, there is a need to have a collaborative research among member countries. Advancement in the area of biotechnology needs to be transferred through training courses or attachments to specific laboratories to enable local scientists to improve on their local commercial cultivars.

Collaboration is sought in the following areas:

1)  Product development and downstream activities (food products, non-food products, health food.

2)  Biotechnological research (development of protocols and identification/development of genes for resistance.

3)  Postharvest physiology (controlled ripening, extension of shelf-life and carotenoid development.
4) Specialized working groups (fusarium, sigatoka, viruses, pests, etc.).

5) Capacity building (training/attachments, scientific visits and workshops on biotechnology/application).
The Philippine banana industry: Status and prospects

Jocelyn E. Eusebio*, Joselito A. Payot and Angelito T. Carpio

Importance

Banana is considered one of the prime fruit commodities grown in the Philippines in terms of hectarage and commercial value. A widely cultivated fruit crop, banana contributes significantly to the country’s employment generation and export receipts. At the farm level, about 5.9 million Filipinos depend on banana growing as an important source of cash income. Both the cooking and dessert varieties are important and nutritious supplement to Filipino diet. An estimated 73% of local fruit consumer prefers banana.

Banana is used in several ways. Fruits are processed into banana cue, puree, jam, jelly, chips, catsup, figs, spreads and preserve. Banana chips, also known as banana crackers or dried bananas is the top dollar earner among processed fruit products.

Industrial products can also be prepared from banana such as ethyl alcohol, flour, dye, floor wax, paste and corkboard. The pseudostem is a good source of fiber and handicraft materials. In commercial plantations, rejects or excess bananas are utilized as swine and cattle feed.

Production and consumption trends

Banana is grown throughout the archipelago wherein large farms are located mostly in the island of Mindanao. The area planted to banana during the 1991-2001 period increased by 22% from 317 108 hectare in 1991 to 386 503 hectare in 2001 (Table 1). On the other hand, Banana production grew by 38% for the same period reaching a maximum volume of 5.06 million tonnes. Production is mainly concentrated in Mindanao where the biggest banana producing provinces of Davao del Norte, Davao del Sur and Davao City of southern Mindanao region, Lanao del Norte of central Mindanao and Misamis Oriental of northern Mindanao are located. Southern Mindanao tops banana production with volume ranging from 1.26-2.24 million tonnes over a period of 10 years (Table 2).

*Director, Crops Research Division, PCARRD, Los Baños, Laguna, Philippines.
### Table 1. Area planted to banana by region from 1991-2001.

<table>
<thead>
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### Table 2. Volume of production of banana in tonnes by region from 1991-2001.

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<td>239.7</td>
<td>240.6</td>
<td>236.6</td>
<td>243.6</td>
<td>201.0</td>
<td>243.5</td>
<td>254.5</td>
<td>256.1</td>
</tr>
<tr>
<td>Central Visayas</td>
<td>157.3</td>
<td>158.6</td>
<td>156.9</td>
<td>162.4</td>
<td>166.0</td>
<td>170.7</td>
<td>179.1</td>
<td>166.5</td>
<td>175.4</td>
<td>182.3</td>
<td>186.5</td>
</tr>
<tr>
<td>Eastern Visayas</td>
<td>205.3</td>
<td>213.2</td>
<td>214.1</td>
<td>228.7</td>
<td>217.3</td>
<td>206.2</td>
<td>216.3</td>
<td>201.5</td>
<td>207.2</td>
<td>224.2</td>
<td>227.0</td>
</tr>
<tr>
<td>Western Mindanao</td>
<td>201.4</td>
<td>203.5</td>
<td>202.1</td>
<td>209.1</td>
<td>206.5</td>
<td>183.5</td>
<td>200.5</td>
<td>163.8</td>
<td>173.7</td>
<td>181.8</td>
<td>184.5</td>
</tr>
<tr>
<td>Northern Mindanao</td>
<td>147.5</td>
<td>153.0</td>
<td>158.2</td>
<td>162.2</td>
<td>165.9</td>
<td>170.1</td>
<td>171.2</td>
<td>130.1</td>
<td>178.2</td>
<td>184.2</td>
<td>205.1</td>
</tr>
<tr>
<td>Southern Mindanao</td>
<td>1 264.8</td>
<td>1 265.1</td>
<td>1 366.5</td>
<td>1 477.1</td>
<td>1 809.5</td>
<td>1 875.5</td>
<td>1 883.5</td>
<td>1 753.5</td>
<td>1 972.7</td>
<td>2 142.2</td>
<td>2 245.1</td>
</tr>
<tr>
<td>Central Mindanao</td>
<td>342.2</td>
<td>356.0</td>
<td>331.0</td>
<td>317.9</td>
<td>302.1</td>
<td>318.0</td>
<td>374.6</td>
<td>382.0</td>
<td>433.3</td>
<td>483.9</td>
<td>514.1</td>
</tr>
<tr>
<td>CARAGA</td>
<td>261.7</td>
<td>259.1</td>
<td>262.0</td>
<td>248.5</td>
<td>247.5</td>
<td>244.1</td>
<td>207.5</td>
<td>188.1</td>
<td>192.1</td>
<td>197.3</td>
<td>197.8</td>
</tr>
<tr>
<td>ARMM</td>
<td>166.2</td>
<td>179.4</td>
<td>188.1</td>
<td>195.7</td>
<td>204.4</td>
<td>198.7</td>
<td>218.5</td>
<td>224.9</td>
<td>290.8</td>
<td>328.7</td>
<td>334.5</td>
</tr>
<tr>
<td>Philippines</td>
<td>3 662.3</td>
<td>3 723.9</td>
<td>3 809.4</td>
<td>3 916.4</td>
<td>4 236.2</td>
<td>4 229.1</td>
<td>4 407.7</td>
<td>4 106.7</td>
<td>4 570.6</td>
<td>4 929.6</td>
<td>5 060.8</td>
</tr>
</tbody>
</table>

The Philippines has identified 80 distinct banana cultivars. The most commonly grown varieties are Cavendish Saba, Lakatan, Latundan and Bungulan. Cavendish is the most popularly grown cultivar by most corporate farms in Mindanao and is highly accepted in the global market. Saba, on the other hand, is the primary cultivar used for making chips/crackers and flour/powder. Basically, chips are the main ingredients for breakfast cereals; trail mixes (used for flavoring) and confections. Latundan and Lakatan are very famous in the local markets, which are always present in Filipinos’ daily meals as dessert. Figure 1 shows that among the major cultivars planted in 2000, Saba (44%) accounts for the highest share in terms of area covered, followed by Latundan (20%), Lakatan (12%) Cavendish (10%) and Bungulan (6%). Figure 2 presents the distribution of major cultivars in terms of volume of production.

![Pie chart showing distribution of major banana cultivars in terms of area covered, CY 2000 (BAS 2001).](image1)

![Pie chart showing distribution of major banana cultivars in terms of volume of production, CY 2000 (BAS 2001).](image2)
From the country’s total banana production (1991 to 2001), 50% are consumed as fresh, 35% are processed for food and 15% for waste. On a per capita basis, consumption is on a downtrend, from 33 kg in 1980 to 23 kg in 1998 (DA-AMAS). This is because the prices of the locally sold banana have skyrocketed, over the years. Table bananas sold in the supermarkets are mostly Cavendish (rejects of exporting private companies) and Lakatan (Gorres, personal communication).

**Export trend**

Among the ten Philippine agricultural exports, banana consistently ranks second to coconut products in terms of dollar earnings (Table 3).

**Table 3.** Agricultural foreign trade statistics - value of principal agricultural exports, million (FOB US$).

<table>
<thead>
<tr>
<th>Item</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut oil</td>
<td>673.43</td>
<td>705.66</td>
<td>342.28</td>
<td>463.94</td>
<td>417.55</td>
</tr>
<tr>
<td>Banana</td>
<td>216.56</td>
<td>217.04</td>
<td>240.70</td>
<td>291.63</td>
<td>297.33</td>
</tr>
<tr>
<td>Pineapple and products</td>
<td>149.55</td>
<td>140.35</td>
<td>137.32</td>
<td>155.95</td>
<td>161.67</td>
</tr>
<tr>
<td>Shrimps and prawns</td>
<td>126.42</td>
<td>129.34</td>
<td>127.61</td>
<td>144.65</td>
<td>123.55</td>
</tr>
<tr>
<td>Tuna</td>
<td>164.61</td>
<td>183.25</td>
<td>129.65</td>
<td>118.26</td>
<td>112.80</td>
</tr>
<tr>
<td>Seaweeds and carrageenan</td>
<td>94.72</td>
<td>64.71</td>
<td>85.59</td>
<td>84.87</td>
<td>71.17</td>
</tr>
<tr>
<td>Dessicated coconut</td>
<td>88.29</td>
<td>72.76</td>
<td>89.18</td>
<td>73.25</td>
<td>63.31</td>
</tr>
<tr>
<td>Sugar</td>
<td>82.71</td>
<td>80.00</td>
<td>62.62</td>
<td>51.71</td>
<td>22.76</td>
</tr>
<tr>
<td>Fertilizer, manufactured</td>
<td>98.95</td>
<td>91.59</td>
<td>44.10</td>
<td>43.63</td>
<td>34.96</td>
</tr>
<tr>
<td>Mango, fresh</td>
<td>40.48</td>
<td>41.74</td>
<td>32.34</td>
<td>34.33</td>
<td>27.98</td>
</tr>
</tbody>
</table>

The Philippines is the only Southeast Asian country that made it to the top five major suppliers of banana in the world in 2000. The country ranked 5th among the world’s banana producers with 3.56 million tonnes or 6.1% of the world production (FAO 2000). India had the biggest share (18.9%) followed by Brazil (9.3%), China (8.9%) and Ecuador (8.6%). Indonesia occupied the 6th rank while Thailand ranked 9th (Table 4).

The major products being exported are fresh banana, chips/crackers and catsup. In 2000, the fresh bananas constitute the main bulk of the country’s export, or almost 98% of the total volume exported (1.62 million metric tons) valued at US$312M (Table 5).
Table 4. Top ten banana-producing countries in the world, in terms of volume of production, 2000.

<table>
<thead>
<tr>
<th>Country</th>
<th>Rank</th>
<th>Production (000 t)</th>
<th>% Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>1</td>
<td>11 000</td>
<td>18.86</td>
</tr>
<tr>
<td>Brazil</td>
<td>2</td>
<td>5 449</td>
<td>9.34</td>
</tr>
<tr>
<td>China</td>
<td>3</td>
<td>5 216</td>
<td>8.94</td>
</tr>
<tr>
<td>Ecuador</td>
<td>4</td>
<td>5 000</td>
<td>8.57</td>
</tr>
<tr>
<td>Philippines</td>
<td>5</td>
<td>3 561</td>
<td>6.10</td>
</tr>
<tr>
<td>Indonesia</td>
<td>6</td>
<td>3 166</td>
<td>5.43</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>7</td>
<td>2 101</td>
<td>3.60</td>
</tr>
<tr>
<td>Mexico</td>
<td>8</td>
<td>1 720</td>
<td>2.95</td>
</tr>
<tr>
<td>Thailand</td>
<td>9</td>
<td>1 720</td>
<td>2.95</td>
</tr>
<tr>
<td>Columbia</td>
<td>10</td>
<td>1 570</td>
<td>2.69</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Kind</th>
<th>2000</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (000 t)</td>
<td>Value (million US$)</td>
</tr>
<tr>
<td>Fresh</td>
<td>1 599.35</td>
<td>291.65</td>
</tr>
<tr>
<td>Chips/crackers</td>
<td>20.32</td>
<td>19.88</td>
</tr>
<tr>
<td>Catsup</td>
<td>1.44</td>
<td>1.28</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1 621.11</td>
<td>312.81</td>
</tr>
</tbody>
</table>


Figure 3 shows the major importing countries of fresh bananas. Japan is the biggest importer (61%), followed by China (16%), Korea (8%), Taiwan (6%) and UAE (6%). On the other hand, the exported chips/crackers reached 20 320 metric tons only and catsup, only 1440 tonnes. Of the total volume of chips exported from 1999-2000, 38% went to Hongkong, 25% to Japan, 17% to Singapore, and 11% to Netherlands (Figure 4).
The Philippines enjoys export advantage over its ASEAN neighbours in terms of production and marketing because of its proximity to the major importing countries and technological advances in the production and handling systems. This is primarily because the infrastructure for export has long been established in Mindanao since the late 1960s.

Production constraints

Despite the bright opportunities presented, the banana industry is also beset with problems, foremost of which are the following:

a. Incidence of major insect pests and diseases

One of the industry constraints consistently identified is the occurrence of destructive and debilitating insect pests and diseases, which significantly reduce the yield and quality of produce. According to the latest surveys conducted, smallholder farmers are now abandoning banana growing particularly Lakatan and Latundan cultivars, because of major diseases such as banana bunchy-top (BBTV), bugtok and fusarium wilt. The most serious leaf disease, black sigatoka, is reduces yield by as much as 80% in small farmers fields. Bugtok disease seriously affects Saba production in Visayas and Mindanao. The impact is most severe for smallholder farmers who do not have the capabilities and resources to manage these diseases.

Recent import risk analysis (IRA) report made by Australia also revealed that occurrence of insect pests and diseases such as moko/bugtok, black sigatoka, freckles and mealybugs are major hindrances to banana importation because their entry, establishment and spread allegedly cause serious impact on domestic trade and industry. Though IRA report have some uncertainties, it is difficult to argue due to lack of reliable information...
The Philippine banana industry: Status and prospects

The trend in moko incidence in commercial plantations but there are still reports of sporadic cases of disease recurrence.

Sigatoka leaf spot diseases of banana are caused by *Mycosphaerella fijiensis* Morlet (black sigatoka) and *M. musicola* Leach and Mulder (yellow sigatoka). The leaf spot diseases destroy banana leaves leading to decrease in yield and premature ripening of fruits. The disease is a major limiting factor in the production of export-quality banana in commercial plantations and smallholder banana farms.

Sigatoka is primarily controlled by regular aerial spray of fungicides causing enormous expense to Cavendish corporate farms. Smallholder farmers who do not have the capability and resources are under the mercy of sigatoka recurring losses as much as 80%.

Viral diseases such as bunchy top and mosaic are widely spread among local cultivars such as cooking bananas, Saba, Cardaba and Morado. There is a growing concern on the behavior of mosaic under Philippine conditions considering the favorable climate, the cultivation of susceptible banana varieties, the presence of abaca (*Musa textilis* Nee) plantations, and other factors (Valmayor 1990).

Banana bunchy top (BBTV) is considered as the most serious disease present in practically all commercial plantations in the Philippines. San Juan (1989) stated that the disease had reached epidemic proportion since it was widespread in both the small and large farms attacking different cultivars planted by the farmers such as Lakatan, Latundan, Bungulan, Saba, Cardaba, Giant Cavendish, Umalag, Señorita and others. Control measures of this disease consist of: a) early disease recognition and prompt eradication of infected plants; b) control of its insect vector, *Pentalonia nigronervosa* coq.; c) use of virus-free planting materials; and d) quarantine for areas that are free from the said disease.

In 1994, rehabilitation of BBT-affected areas was initiated in
southern Mindanao, southern Luzon and northern Luzon areas. There were some problems encountered by the project, i.e. farmers’ attitude, insufficient source of clean planting materials and lack of continuous support from the local government units (LGUs).

Based on the accomplishments of the project on rehabilitation of BBTV-affected areas, success can be attained in small farms provided the following conditions can be met: a) education of the farmers and agricultural technicians in the disease symptomatology, insect vector and control measures; b) cooperation of the whole community in the prompt eradication of infected plants; c) availability of virus-free planting materials; d) availability of technologies to improve production; and e) continuous support of concerned local government units.

For insect pests, the most destructive is the corm weevil or corm borer (Cosmopolites sordidus Germar) whose larvae feed on the corm by making tunnels in it. Control measures consist of trapping and making the area around the mat/hill always clean. For heavy infestation, the use of insecticides such as pirimphos-ethyl and chlorpyritos are recommended at manufacturer’s recommended dosage. Thrips (Thrips florum Schmutz) and Chaetanaphotrips signipennis Begnall) feed on the fruit peel resulting to corky scab or reddish brown discoloration. Severely damaged fruits may split open. Control measures consist of bud injection of insecticide solution 3-5 days after shooting and by bagging the inflorescence with chlorpyriffos-impregnated polyethylene bag. The insecticides used for bud injection are chloropyriffos, methyl parathion (encapsulated), methamidophus and phoshamidon.

b. Production systems/practices

Four (4) distinct production systems evolved after long years of cultivating banana in the Philippines (Valmeyor 1990). These are:

1. Backyard production system. This is characterized by the diversity of cultivars in the different regions. Cultivars planted by farmer is dictated by family needs (i.e. dessert or cooking), quality preferences of the household members, prevalence of insect pests and diseases, climatic conditions and ease of production. Very minimal input goes into this system of production. Only compost and animal manure are used as fertilizers. Labor is supplied entirely by family members. Common problem arises in this system as most of bananas planted receive minimal inputs and attention; hence, prevalence of pests and their spread is hardly
minimized. Some farmers visit the field only when it is time to harvest the fruits.

2. **Systematic mixed crop production.** In this system, banana can be a primary crop or a secondary crop, a permanent or temporary crop. As primary crop in the mixed cropping system, it is usually interplanted with annual crops (taro, ginger, sweet potato, corn and many other vegetable crops).

In southern Philippines, banana is raised as a temporary crop to the young rubber and durian trees to serve as an early source of cash income while the permanent crops are still growing. Once the permanent crops are established or when banana starts to interfere with the growth of the primary crop, the banana stands are cut and/or taken out of the area.

3. **Commercial smallholder plantation.** This production system promotes banana as a monocrop in areas ranging from 2 to 20 hectares. Common varieties are Lakatan, Latundan, Saba, and Señorita, which are intended for the domestic market. The choice of varieties is limited by consumers’ preference and suitability to the prevailing agroclimatic conditions of the location. Management practices employed include fertilizer application, weeding, replanting and pest control. However, these are done less extensively as in agribusiness plantations.

4. **Corporate farms.** This production system caters to the strict requirements of the export market. A single cultivar is usually grown in large tract of land. The cultivars are: Giant Cavendish, Grande Naine, Umalag and Señorita.

The enterprise is capital-intensive with heavy investment in plantation infrastructures. Production practices are applied at optimum levels and quality and yields are high.

In the Philippines, these plantations are found in Mindanao, which is noted for its favorable agroclimatic conditions and outside the ‘typhoon belt’ area.

According to Recel (1996), big plantations rely heavily on the use of chemicals to effectively control diseases. However, such tremendous increase in pesticide use has consequential deleterious effects on human health and environment.

Small farmers who cannot afford the high cost of chemical control for insect pests and diseases are left to sell lesser volume
of poor quality fruits because most of these diseases affect both the yield and quality of the fruit.

c. Environmental problems

The increased rate and frequency of applications of synthetic pesticides and chemical fertilizers by large corporate plantations resulted to the gradual degradation of the soil resources and triggered the emergence of new generations of insect pests and diseases. The new generation require more toxic pesticide compounds being applied, not only more frequently but also more concentrated for effective control. Hence, the gradual build-up of toxic residues found their way to the water table, to the rivers that drain to bigger bodies of water, to the atmosphere that is taken up by the plants and animals and finally get into the food chain.

The major operational activities in commercial banana production for export such as plant nutrition, plant, and fruit care are heavily dependent on the use of chemical fertilizers and synthetic pesticides. On banana crop protection alone, roughly about 20 to 23 liters of liquid synthetic fertilizers per hectare per year and about 400 to 950 kilograms of pesticides in solid forms are commonly applied with amounts depending on the severity of insect pest infection and disease infestation and the financial capability of the company or producers.

In plant nutrition and soil amelioration, about 6 to 15 tonnes of chemical fertilizers and inorganic ameliorants per hectare per year are usually applied with amounts depending on the native fertility of the soil, the nutrient requirement of the plant, plant population density and others.

However, with the global trend towards the increasing demand for organically produced food products, abusive use of synthetic pesticides and chemical fertilizers are gradually being replaced with organic fertilizers and pesticides.

d. Other constraints of the banana industry

- Lack of storage facilities in ports where voluminous quantities of banana are assembled before they are transported to market centers. Ports do not have available facilities to provide shade, if not the ideal holding condition

- Lack of awareness on appropriate handling practices by traders especially in traditional banana varieties
Lack of available tissue-cultured planting materials especially for traditional farmer varieties

Inadequate production/post-production practices, predominance of subsistent backyard plantings, poor marketing systems and lack of quality standard for fresh and processed products for Saba, Lakatan, Latundan and other farmer varieties

Current banana R&D activities, programs and institutions involved

Institutions involved in banana R&D and their areas of specialization

Both the private and public sectors are active in banana R&D, with the private sector, like the corporate farms, playing a major role by maintaining their respective research departments to increase production efficiencies. R&D in the Philippine public sector is carried out by the Department of Science and Technology (DOST), the Department of Agriculture (DA), and the State Colleges and Universities (SCUs).

The DOST’s Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD) is mandated to provide central leadership direction and coordination of R&D efforts in agriculture, natural resources and environment. To implement this mandate, PCARRD organized the National Agriculture and Resources Research and Development Network (NARRDN) and the National Commodity R&D Teams and Experts Pool. The NARRDN is composed of national and regional research centers and cooperating stations with functions of conducting and verifying research on specific commodities and disciplines. Banana R&D activities are carried out through this network.

Recent developments in the industry shows that gaps/problems still exist. These problems are translated into R&D Priority Areas with institutions working on banana and plantain from both the government and private sector. The different R&D institutes/centers and their areas of involvement/activities are as follows:

a. Propagation and evaluation of tissue culture-derived planting materials
   - Department of Agriculture (DA)
     - Bureau of Plant Industry (BPI)
     - Davao National Crop R&D Center (DNCRDC)
- Baguio National Crop R&D Center (BNCRDC)
- La Granja National Crop R&D Center (LGCRDC)
- Regional Offices/Integrated Agricultural Research Centers
  - DA-CARAGA Region
  - DA-CeMIARC
  - DA-EVIARC
- State colleges and universities (SCUs)
  - University of the Philippines at Los Baños (UPLB)
    - Institute of Plant Breeding (IPB)
    - Department of Horticulture
  - Quirino State College (QSC)
  - Isabela State University (ISU)
  - Nueva Vizcaya State Institute of Technology (NVSIT)
  - Ramon Magsaysay Technological University (RMTU)
  - Northern Mindanao State Institute of Science and Technology (NORMISIST)
  - University of Southern Mindanao (USM)
  - Mariano Marcos State University (MMSU)
  - Don Mariano Marcos Memorial State University (DMMMSU)
- Private sector
  - Twin Rivers Research Center
  - DOLE
  - STANFILCO
  - LAPANDAY
  - Member-agencies of the Philippine Association for Plant Tissue Culture

b. Genebanking, collection, characterization, maintenance of germplasm and banana-based orchards (DA and SCUs)
  - DA - BPI-DNCRDC
  - UPLB-Institute of Plant Breeding (IPB)
  - Mariano Marcos State University (MMSU)
  - Quirino State College (QSC)

c. Breeding and variety trials (DA and SCUs)
  - UPLB-IPB
  - DA-BPI-DNCRDC
  - QSC
  - MMSU

d. Development of varieties resistant to BBTV
  - UPLB-IPB

e. Crop production and farming systems (DA-SCUs)
• UPLB-Farming Systems and Soil Resources Institute (FSSRI)
• UPLB-Department of Horticulture
• University of Southern Mindanao (USM)
• QSC
• BPI-DNCRDC
• DA-Agusan del Sur
• DA-Bohol Experiment Station
• DA-CAR

f. Crop protection (DA and SCUs)
   - Disease resistance trial
     • DA-Apayao
     • BPI-DNCRDC
     • UPLB-Dept. of Plant Pathology
   - Bugtok Studies
     • BPI-DNCRDC
     • NORMISIST
   - Quarantine
     • DA-BPI Manila
   - Serological techniques
     • UPLB-BIOTECH
     • UPLB-NCPC

g. Postharvest handling
   - Maturity/ripening indices
     • BPI-DNCRDC
     • UPLB-Postharvest Horticulture Training and Research Center (PHTRC)
   - Postharvest, handling, physiology and physico-chemical studies
     • UPLB-PHTRC
   - Grading and standard
     • Department of Trade and Industry (DTI)

h. Food processing and utilization
• DOST-Industrial Technology Development Institute (ITDI)
• DOST-Food and Nutrition Research Institute (FNRI)
• UPLB-Institute of Food Science and Technology (IFST)
• BPI-Manila

i. Fiber extraction/fibreboard and corrugating medium
• DA-Fiber Industry Development Authority (FIDA)
• DOST- Forest Products Research and Development Institute (FPRDI)
Opportunities and thrusts

The strength of the Philippine banana industry lies on the big hectarage, which is little, more than half (53.8%) of the total land area planted to fruits. The country is also blessed with favorable climate well-suited for growing bananas all-year round and there are cultivars accepted in domestic and export markets. The competitiveness of Philippine bananas in the global market is well established especially with fresh banana. This inspires the stakeholders to support the industry through the years, which generated remarkable dollar earnings for the country.

Over the years, several technologies have been developed addressing the major concerns of the industry, namely: production of quality fruits, availability of disease-free planting materials, control of insect pest and diseases, reduction of postharvest losses, and new improved processed products. However, more activities have to be done to further enhance the productivity of banana growers.

Considering the research breakthroughs on banana derived from previous programs, current research thrusts are focuses on S&T interventions that will help the banana industry maintain its niche in the export and domestic markets. The major concerns will be on low-cost production, productivity enhancement and quality improvement of Saba, Lakatan and Latundan for fresh local market as they compete with other fruits.

For the next five years, activities will be carried out on the following priority research areas/thrusts:

A. Pre-production
   1. Variety
      • Development of long-term germplasm conservation (e.g. tissue culture, cryopreservation)
      • Development of resistant cultivars to major pests with improved horticultural characteristics through genetic engineering
   2. Propagation
      • Further improvement of an efficient micropropagation technique
      • Identification of strategic locations of tissue-culture laboratories and technology transfer activities

B. Production
   1. Planting density
      • Establishment of appropriate planting density for major
cultivars

2. Nutrition
   • Establishment of critical nutrient levels for major cultivars
   • Nutrient requirements of major cultivars during fruit growth and development

3. Water relations
   • Determination of water requirements based on crop phenology
   • Influence of water on fruit growth and development

4. Cultural management/cropping systems
   • Environment-specific management options for major cultivars
     o Characterization of root/shoot growth and function of major cultivars
   • Establishment of sustainable banana-based cropping system
   • Establishment of cropping system for typhoon-prone areas

5. Crop protection
   • Determination of pest biology, behavior and ecology
   • Determination of disease epidemiology
   • Control strategies for moko, bugtok, and sigatoka
   • Improved IPM programs for major cultivars against BBTV, sigatoka and fusarium wilt

6. Postharvest system
   • Determination of maturity indices, storage requirement, ripening regulation and physiological disorders
   • Improvement of packaging, grading and transport
   • Development of postharvest treatment to reduce loss due to insect pests and diseases

7. Processing, utilization and promotion
   • Establishment of processing facilities in production sites
   • Development of new high value and novel processed products and utilization of by-products
   • Development of standards for consistent quality of processed products
   • Development of innovative and appropriate packaging for banana products
   • Banana processor-assisted process standardization, marketing and promotion to create new markets for banana products
8. Socio-economics and marketing
   - Ex-ante socio-economics evaluation of R&D project on banana
   - Analysis and advocacy of policy options to enhance the development of small-hold banana sub-industry
   - Assessment of factor conditions that affect the growth and competitiveness of the banana industry
   - Analysis and development of entrepreneurial skills among the small-hold farmers in the country
   - Analysis of marketing efficiency and development of innovative marketing strategies for small-hold banana growers

The Department of Agriculture program focuses on improved product development, postharvest handling and enhancement of productivity of banana farms through control and management of virus and other diseases, validation of nutrient values and nutritional requirements of banana plant, cultivar development for disease resistance, population density studies and biotechnology (BBTV gene constructs).

**Proposed areas of collaboration**

Regional cooperation is of utmost importance particularly among countries of the Asia-Pacific Region where there is a common ecological conditions, problems and thrusts. Their R&D activities are relevant to each of their neighbors. Such conditions call for a unified effort among the member countries to hasten development of the banana industry in the region:

This meeting is very important for all the participating countries to identify areas for collaborative R&D to further strengthen our efforts in the development of the banana industry. As such, the following are proposed areas of collaboration in banana and plantain research and development for the region:

a. Research

1. Improved propagation techniques for efficient plantlet production
2. Strain diversity of major viruses (BBTV, CMV, BBrMV and BSV) and cross protection studies
3. Development of disease-resistant varieties
4. Vulnerability of disease-free planting materials in the field
5. Documentation of loss assessment in the field due to major insect pests and diseases and improper postharvest handling and practices.

b. Development

1. Establishment and maintenance of the following centers/programmes and facilities back up with strong policy recommendations and support:
   - Virus indexing centers, seedling certification program and accreditation of tissue culture laboratories
   - National rehabilitation/eradication program from major virus diseases
   - Strict quarantine regulation and enforcement

2. Regular training of researchers regarding on advance technologies in banana production and post-production.

3. Mutual exchange of elite germplasm materials

4. Packaging, collection and distribution of relevant information on banana for distribution to scientists, growers and policy makers

References


CRD-PCARRD. 2002. Fruits R&D Status and Directions (Mango and Banana). Crops Research Division, PCARRD.


during the Fruit Cluster Meeting at PCARRD, Los Baños, Laguna, July 1998.

Status of banana R&D, production and consumption in Papua New Guinea

Rosa Naipo Kambouou*

Introduction

Banana is a major food crop in Papua New Guinea (PNG). It is the dominant staple crop in most farming systems in the lowland areas of the country and ranks second in importance after sweet potato in terms of production and consumption. PNG is an important centre of genetic diversity of wild and cultivated bananas, with the greatest number of Musa species. The great diversity in the cultivated diploids (AA) has made PNG the only country in the world where diploid bananas are of significance in agricultural food production (Stover and Simmonds 1987).

Cooking bananas are often distinguished from sweet or dessert bananas, although this is somewhat an artificial distinction. In PNG, more cooking bananas are produced and consumed than dessert types. The diploid cultivars are mostly cultivated in wet lowland areas of the country, including the islands. The triploids, ABB groups, are harder and are grown mostly in dry lowland areas, along the Papuan coast and the Markham/Ramu valleys. The other triploid group, the AAB, are grown mostly in the highland areas of the country. All bananas produced are consumed in the country. The subsistence production is mostly for household consumption and the surplus is sold in urban markets for cash. There are few semi-commercial growers, who grow dessert varieties for the fresh fruit market.

Even though banana is the second most important food crop of the country, it has received little R&D attention. While the international banana emphasis is on commercial dessert bananas, most production in PNG is based on starchy cooking types grown under subsistence production systems. Very little research on cooking bananas has been conducted in PNG (King 1986).

The National Agricultural Research Institute (NARI) is currently looking at banana as a component in the farming systems research and not as a separate entity. The Institute is currently maintaining the national field genebank collection at Laloki and working collections at Bubia, Keravat and Aiyura.

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This paper will discuss the current status of banana R&D activities undertaken in the country and highlight the constraints that the banana production is facing. Some thoughts on possible areas of collaboration and opportunities and thrusts to further strengthen the network arrangements will also be discussed.

**Banana industry status**

Banana production in the country is still in the hands of the subsistence farmers and the 85% of the people who live in rural areas. Well over 80% of the bananas produced are cooking types, grown mainly for household consumption and surplus is sold in urban fresh food markets for cash income. Less than 20% of the bananas produced in the country are dessert types grown mostly by semi-commercial set-ups run by institutions or private growers for the urban fresh fruit market.

**Banana production and yield**

There are no recent national level data on banana production for PNG. However, the nationwide household consumption survey that was carried out in 1996 as part of the World Bank Poverty Assessment Project, gives some estimates of household production and consumption. Gibson (2001) reported an estimate of 413 000 tonnes of bananas produced in 1996 and each person was producing around 85 kg of bananas. The Food and Agriculture Organisation (FAO) estimates for banana production for PNG in 1996 was 665 000 tonnes (Waterhouse et al 1999). These figures are only estimates and may not reflect the true situation in the country. It is very difficult to accurately assess the area under production and the quantity produced and consumed under subsistence situation.

The bunch yield/hectare depends very much on the varieties, the growing conditions and the cultural practices. A survey on the banana production, marketing and consumption carried out in 1986 to 1988 revealed the mean bunch yield of 6.0 t/ha/household was obtained from a single harvest of diploid bananas (Kambuou 2001). The mean bunch weight of diploid bananas was 5.4 kg. The triploids have heavier bunches and would give a higher mean weight of bunch per hectare per household.

The acreage under dessert bananas is small. The subsistence farmers grow their dessert bananas amongst the cooking bananas and other food crops in a mixed cropping manner. There are few semi-commercial establishments in PNG that grow dessert bananas. The Pacific Adventist University (PAU) outside Port Moresby is currently growing
six hectares of varieties Williams and Cavendish for the Port Moresby fresh fruit market and the students’ mess. They are producing around 27-30 tonnes of banana per hectare. The students are consuming 10% of what is produced and 90% is sold to the fresh fruit markets in Port Moresby.

**Consumption and trade**

Gibson (2001) reported that each person in PNG was consuming around 83 kg of bananas in 1996 with the rural areas consuming the highest quantity of 90 kg per head. The FAO estimates imply an average banana consumption in PNG of 84 kg per head in 1998 (Waterhouse et al 1999). The FAO estimates closely related to the findings of the PNG household survey conducted in 1996.

The importance of banana as a food crop is again apparent in providing 6.9% of the national calories and 7.4% of the rural household calories (Gibson 2001) (Table 1).

**Table 1.** Share of total calories (%) provided by bananas and other staple food crops of PNG.

<table>
<thead>
<tr>
<th>Food Crops</th>
<th>PNG</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potato</td>
<td>26.7</td>
<td>30.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Banana (cooking &amp; dessert)</td>
<td>6.9</td>
<td>7.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Cassava</td>
<td>2.8</td>
<td>3.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Taro &amp; Xanthrosoma</td>
<td>6.6</td>
<td>7.3</td>
<td>2.2</td>
</tr>
<tr>
<td>Sago</td>
<td>6.5</td>
<td>6.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Yam</td>
<td>2.4</td>
<td>2.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Irish potato</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Other food crops &amp; imported food</td>
<td>47.9</td>
<td>43.0</td>
<td>79.5</td>
</tr>
</tbody>
</table>

Source: Gibson 2000. The economic and nutritional importance of household food production in PNG.

The average prices of cooking and eating bananas sold in urban markets throughout the major centres of PNG during January to December 2001 are given in Table 2. It is evident that bananas sold in Mt Hagen and Port Moresby markets are more expensive than other centres. This is also true for other food crops.

The data indicate a large spread of prices between markets such as Popondetta where banana production is low due to few farmers growing the crop, compared to Rabaul where every household is at least growing banana. The price for a bunch (five hands) of diploid
Common banana varieties grown by farmers

The main dessert varieties grown on semi-commercial scale are the Dwarf, Medium and Tall Cavendish and Gros Michel. Subsistence farmers grow more than 30 dessert landraces, depending on localities. The common types grown throughout the country are: Yawa (Pisang Awak - ABB), Mossmun (Pisang Mas - Sucrier AA) and Sogeri Biku (landrace - AA) in the lowlands and Suga (landrace - AAA) in the highland areas. It would be difficult to estimate the production of dessert bananas by subsistence farmers. The list of the common dessert varieties and landraces of bananas grown in PNG is given in Table 3.

There are well over 200 landraces of cooking bananas. Different varieties and landraces are grown by farmers depending on consumers’ preference and the locations. The common bananas grown in the dry lowlands areas are the Kalapua types from the ABB group. Farmers

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**Table 2.** Average price for bananas sold in seven major centres in PNG during Jan - Dec 2001 (in PNG Kina*/kg).

<table>
<thead>
<tr>
<th>Type of banana</th>
<th>Port Moresby</th>
<th>Lae</th>
<th>Madang</th>
<th>Goroka</th>
<th>Rabaul</th>
<th>Popondetta</th>
<th>Mt Hagen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dessert/ sweet</td>
<td>3.12</td>
<td>0.79</td>
<td>0.70</td>
<td>0.63</td>
<td>0.63</td>
<td>1.91</td>
<td>3.99</td>
</tr>
<tr>
<td>Cooking</td>
<td>1.45</td>
<td>3.57</td>
<td>3.65</td>
<td>1.24</td>
<td>0.50</td>
<td>3.86</td>
<td>2.96</td>
</tr>
</tbody>
</table>

in these areas grow more than 20 different Kalapua landraces. The diploid landraces from the AA group are mostly grown in the wet lowland areas of the country and the AAB types are grown in the highland areas. The list of the commonly grown cooking bananas is given in Table 4.

### Uses of bananas

Banana fruits are consumed mainly as staple food, prepared in different ways. The dessert types are left to ripen before they are eaten or sold. Some cooking landraces can be eaten ripe as well. For example, the popular Daru cultivar is a triploid ABB, a cooking type, but can also be eaten as dessert banana. A good portion of banana fruits is fed to pigs.

In addition to food, banana plants are used for other household purposes as well. The leaves are used extensively for weaving baskets and mats, as wrapping for food for the market and cooking, as coverings over food from flies, as tablecloths and as plates for eating as well as cup for drinking soup. The old leaves are used in wrapping up banana bunches (bunch covers) for protection against bats and birds. The rural people use the large leaves of triploid bananas as umbrella during rainy season.

The dried midrib of leaves and the dried pseudostem make good rope for tying purposes.

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### Table 3. List of common dessert bananas grown in PNG.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Local/Vernacular name</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Dwarf Cavendish</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td>(2) Medium Cavendish</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td>(3) Tall Cavendish</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td>(4) Yawa</td>
<td>Yawa (Pisang Awak)</td>
<td>ABB</td>
</tr>
<tr>
<td>(5) Gros Michel</td>
<td>AAA</td>
<td></td>
</tr>
<tr>
<td>(6) PNG 052</td>
<td>Yenai (Pisang Mas)</td>
<td>AA</td>
</tr>
<tr>
<td>(7) PNG 131</td>
<td>Daru</td>
<td>ABB</td>
</tr>
<tr>
<td>(8) PNG 175</td>
<td>Mossmun (Pisang Mas)</td>
<td>AA</td>
</tr>
<tr>
<td>(9) PNG 294</td>
<td>Sar</td>
<td>Fe’i</td>
</tr>
<tr>
<td>(10) PNG209</td>
<td>Suga banana</td>
<td>AAA</td>
</tr>
<tr>
<td>(11) Sogeri biku</td>
<td>(Similar to Pisang Berlin)</td>
<td>AA</td>
</tr>
</tbody>
</table>

**Note**: There are over 30 dessert cultivars/landraces of banana grown by subsistence farmers in PNG.
### Table 4.

List of cooking bananas commonly grown in Papua New Guinea.

<table>
<thead>
<tr>
<th>PNG Number</th>
<th>Local/Vernacular Name</th>
<th>Genotype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. PNG 002</td>
<td>Gulum</td>
<td>AA</td>
</tr>
<tr>
<td>2. PNG 004</td>
<td>Vudu Papua or Babi</td>
<td>AA</td>
</tr>
<tr>
<td>3. PNG 013</td>
<td>Kasaka</td>
<td>AA</td>
</tr>
<tr>
<td>4. PNG 014</td>
<td>Navaradam</td>
<td>AA</td>
</tr>
<tr>
<td>5. PNG 020</td>
<td>Aivip</td>
<td>AA</td>
</tr>
<tr>
<td>6. PNG 021</td>
<td>Lalalalur</td>
<td>AA</td>
</tr>
<tr>
<td>7. PNG 027</td>
<td>Taputuput</td>
<td>AA</td>
</tr>
<tr>
<td>8. PNG 034</td>
<td>Auko</td>
<td>AB</td>
</tr>
<tr>
<td>9. PNG 038</td>
<td>Mpiajjah</td>
<td>AA</td>
</tr>
<tr>
<td>10. PNG 043</td>
<td>Waimara</td>
<td>AA</td>
</tr>
<tr>
<td>11. PNG 044</td>
<td>Hung tu</td>
<td>AA</td>
</tr>
<tr>
<td>12. PNG 101</td>
<td>Kekiau</td>
<td>AA</td>
</tr>
<tr>
<td>13. PNG 107</td>
<td>Mamakila</td>
<td>AA</td>
</tr>
<tr>
<td>14. PNG 110</td>
<td>Apindikay</td>
<td>AA</td>
</tr>
<tr>
<td>15. PNG 111</td>
<td>Avalira</td>
<td>AA</td>
</tr>
<tr>
<td>16. PNG 118</td>
<td>Tukuru</td>
<td>ABB</td>
</tr>
<tr>
<td>17. PNG 119</td>
<td>Katual Vunalir</td>
<td>AA</td>
</tr>
<tr>
<td>18. PNG 120</td>
<td>Lagur Vunalir</td>
<td>AA</td>
</tr>
<tr>
<td>19. PNG 131</td>
<td>Daru</td>
<td>ABB</td>
</tr>
<tr>
<td>20. PNG 141</td>
<td>Tukuru No.2</td>
<td>ABB</td>
</tr>
<tr>
<td>21. PNG 142</td>
<td>Tagomor</td>
<td>AA</td>
</tr>
<tr>
<td>22. PNG 145</td>
<td>Kalapua No.2 (large Kalapua)</td>
<td>ABB</td>
</tr>
<tr>
<td>23. PNG 146</td>
<td>Luba</td>
<td>AAB</td>
</tr>
<tr>
<td>24. PNG 153</td>
<td>Bud</td>
<td>AA</td>
</tr>
<tr>
<td>25. PNG 154</td>
<td>Kahur</td>
<td>AA</td>
</tr>
<tr>
<td>26. PNG 159</td>
<td>Maleb</td>
<td>AA</td>
</tr>
<tr>
<td>27. PNG 160</td>
<td>Gonub</td>
<td>AA</td>
</tr>
<tr>
<td>28. PNG 161</td>
<td>Manameg (red)</td>
<td>AA</td>
</tr>
<tr>
<td>29. PNG 163</td>
<td>Manameg (green)</td>
<td>AA</td>
</tr>
<tr>
<td>30. PNG 165</td>
<td>Bago</td>
<td>AA</td>
</tr>
<tr>
<td>31. PNG 171</td>
<td>Dwarf Kalapua</td>
<td>ABB</td>
</tr>
<tr>
<td>32. PNG 184</td>
<td>Enar</td>
<td>AA</td>
</tr>
<tr>
<td>33. PNG 203</td>
<td>Kerua</td>
<td>AAB</td>
</tr>
<tr>
<td>34. PNG 206</td>
<td>Rukumamb Tambey</td>
<td>AAB</td>
</tr>
<tr>
<td>35. PNG 207</td>
<td>Rukumamb</td>
<td>AAB</td>
</tr>
<tr>
<td>36. PNG 227</td>
<td>Tango</td>
<td>AA</td>
</tr>
<tr>
<td>37. PNG 231</td>
<td>Sena</td>
<td>AA</td>
</tr>
<tr>
<td>38. PNG 241</td>
<td>Bengani (Hoodomadare)</td>
<td>ABB</td>
</tr>
<tr>
<td>39. PNG 242</td>
<td>Jaruda</td>
<td>AA</td>
</tr>
<tr>
<td>40. PNG 262</td>
<td>Kwince</td>
<td>AAB</td>
</tr>
<tr>
<td>41. PNG 272</td>
<td>Sraeke (one hand)</td>
<td>AAB</td>
</tr>
<tr>
<td>42. PNG 288</td>
<td>Tainga</td>
<td>AA</td>
</tr>
<tr>
<td>43. PNG 301</td>
<td>Papat Wung</td>
<td>AA</td>
</tr>
<tr>
<td>44. PNG 307</td>
<td>Kupulik (two hands)</td>
<td>AAB</td>
</tr>
<tr>
<td>45. PNG 333</td>
<td>Loibwa</td>
<td>AA</td>
</tr>
<tr>
<td>46. PNG 338</td>
<td>Gilasalasa</td>
<td>AA</td>
</tr>
<tr>
<td>47. PNG 191</td>
<td>Bene</td>
<td>AAB</td>
</tr>
</tbody>
</table>

Note: There are over 200 landraces of cooking bananas grown by subsistence farmers in PNG. The 47 identified in the above Appendix are preferred by consumers.
Production constraints

The decline in banana production in PNG is due to a number of factors. The main factors are pests and diseases, climatic factors, poor farmer management practices, declining soil fertility, lack of market infrastructure, inadequate R&D technologies appropriate for adoption by farmers, limited credit facilities for farmers, poor storage facilities for fresh fruits, lack of know-how on downstream processing and poor marketing strategy.

Climatic factors

The climatic pattern has changed so much in the last 5-15 years that it has severely affected the subsistence way of farming. Rainfall patterns have changed throughout the country. The dry areas are now experiencing longer dry seasons and the wetter areas are experiencing a lot of rain, causing severe landslides and floods. This has forced farmers to grow landraces that are able to grow under adverse climatic conditions, thus losing diversity on farm. Climate change has also created a conducive environment for pest and disease build up and outbreaks of pests such as locusts and armyworm.

Pests and diseases of bananas

The major insect pests of bananas that are of some concern to the farmers are banana skippers (Erionota thrax), the fruit flies (Bactrocera musae) and banana scab moth (Nacoleia octasema). The economic yield reduction caused by these pests is not fully researched in PNG. However, Waterhouse (1999) reported that banana skipper could cause bunch weight loss up to 28% with 50% leaf defoliation.

The most noticeable diseases of bananas in PNG are the leaf spot complex. These include black sigatoka (Mycosphaerella fijiensis), cordana (Cordana musae), black cross (Phyllachora musicola) and freckle (Ramichloridium musae). Sharrock and Jones (1989) reported no firm evidence that yellow sigatoka, the disease that black sigatoka is known to have replaced in other countries (Mycosphaerella musicola), ever existed in PNG. The leaf spot complex mostly affects the diploid AA and the AAA groups. The triploid ABB groups are resistant, particularly to black sigatoka. Leaf spot diseases are not a threat to subsistence banana production because of the resistance and tolerant materials and the diversity in banana genomes present in PNG.

The two lethal diseases of bananas, the blood disease or bacterial wilt and the fusarium wilt or panama disease have been reported to spread to the Irian Jaya Province of Indonesia (Davis et al 2001). Blood disease
is not yet present in PNG, while the fusarium wilt is currently present in three locations in PNG, along the Irian Jaya-PNG border. These diseases would be a serious threat to the subsistence banana production if and when they arrive and establish in PNG.

**Inadequate practical research targeted at subsistence production and limited understanding of the traditional farming systems**

The current research agenda has not given much weight to banana research, except for germplasm collections and maintenance. More emphasis should be given to banana farming systems R&D. The new technologies that are developed should take into account farmers’ knowledge, practices and attitudes and be appropriate for small farmers’ use. Banana is a cultural crop in PNG, where tradition plays a major role in determining the growing of certain types or landraces for special events. Researchers need to be aware of farmers’ practices, the kind of landraces they grow and how they relate these landraces to the social events that are taking place.

**Poor farmer management practices**

In most areas of PNG, subsistence farmers are still practising ‘shifting cultivation. Farmers are growing bananas with other food crops in a mixed cropping manner, often at very high densities. Management input is very low, in terms of labour for weeding, propping, removing dried leaves and earthing soil around banana bases. No mulch is used in the gardens, all weeds are gathered at the side and burnt. Farmers do not desucker their bananas. Suckers are left to grow and produce bunches or are removed as planting materials for new gardens. Subsistence farmers aim mainly at producing bananas for the household consumption and therefore are not too concerned about yield of banana. The traditional technique of covering banana bunches only applies to certain areas and for specific landraces that are selected for customary purposes. Most areas in PNG do not cover banana bunches and therefore are heavily subjected to damage by bats, birds or insects.

**Declining soil fertility**

It is evident in some parts of the country like the Gazelle Peninsula and some areas of the Simbu Province in the highlands of PNG, that farmers are experiencing shortage of arable land for farming. This is due mainly to population pressures and the expansion of good arable land under cash crops such as cocoa, coffee and oil palm. Farmers are not able to shift their gardens to new sites and therefore are forced into shortening the fallow period, which used to be 10-15 years, now
to 3-5 years. Portion of land allocated to a family by the clan is also getting small as family size increases over the years. Rural families are experiencing difficulties to produce good crops due to overuse of their piece of land. Declining soil fertility is a problem throughout the country and may be very serious in certain areas where population pressure is high.

*Lack of market infrastructure and limited credit facilities*

During the recent Provincial Consultation survey carried out by NARI towards the development of the National Research Priority Setting, it was identified that lack of market infrastructure has discouraged farmers to expand on their food crop production. The road networks from the rural areas to the urban centres are inaccessible or are not in place compounded by lack of reliable transport system from the place of production to the market. In areas where it is accessible, the transport cost is often very high for farmers to afford.

The fresh produce markets in the urban centres are all open markets, where farmers sell their produce and at the end of the day if they do not sell their produce, they take them back to the villages. A lot of wastage occurs as a result, which can discourage farmers to produce for the market.

To commercialise banana production, farmers need assistance from the government to help them set up their businesses. There are credit schemes or facilities available in PNG, but their conditions are not favourable for subsistence farmers who do not have assets apart from their own traditional land. The farmers need capital to purchase farm equipment and implement as well the necessary infrastructure to grow bananas. It is very difficult for a subsistence banana grower to get help from the credit facilities currently available.

*Lack of postharvest facilities and know-how on downstream processing*

Postharvest R&D in PNG is lacking. Proper packaging and storage facilities are not developed or available in the country. The semi-commercial dessert banana growers have their own small coldroom facilities and do their own packaging and transporting to the fresh fruit market. Establishment of appropriate postharvest facilities by the government would encourage the farmers to expand their production.

Banana is bulky and highly perishable as fresh produce and therefore needs to be made into other food products that have longer shelf life and can be easily transported. The knowledge and technologies on
processing fresh food crops into other products are available elsewhere and should be investigated for bananas.

*Inadequate delivery of support services (extension) and limited technical manpower*

The delivery mechanism through government service providers is very ineffective and needs to be properly developed and staff to better assist the farmers in the rural areas of the country. Information and technology providers should use other service providers like the Non-Government Organisations (NGO) agencies. More technical and skilled workers are required on banana research.

*Lack of appropriate machinery for production*

Lack of appropriate machinery for farming is a big problem throughout the country. Subsistence farmers are unable to purchase basic farm machinery and implements because of high prices and service back-ups are either poor or very expensive.

Investigation into development and bulk production of appropriate farm machinery, implements and tools would help farmers to boost their banana production.

**Current banana research and development activities and institutes involved**

R&D work on bananas in PNG is minimal at this stage. Banana has been considered with other food crops in the farming systems research agenda, but not as an entity on its own. Research on nutrition and water, postharvest and integrated pest management on banana has not been looked at in PNG. Production of banana in the country is mainly focusing on cooking types as food crops and by subsistence farmers.

NARI is perhaps the only institution in the country that is doing some work on bananas. The Institute is currently maintaining the national banana germplasm collection and the working collections at various research locations throughout the country where suitable farmer cultivars or landraces are selected, multiplied and distributed to farmers for production. There are no service providers that are specifically involved in banana work. The farmers themselves effectively distribute planting materials of bananas and other crops.

**PNG banana species**

Simmonds (1956) and Argent (1976) pointed out that PNG is an
important centre of wild banana distribution although Malaysia is
the recognised origin of bananas. Cultivated bananas belong to the
_Eumusa_ section of the family Musaceae. They are natural hybrid
polyploids, comprising of diploids, triploids and tetraploids. The other
edible bananas are the Fe’i types belonging to the _Australimusa_ section.
This group of banana have originated from PNG, but are not as
important as the edible _Eumusa_ types (Bourke 1976). Apart from the
cultivated edible varieties, there are many wild bananas in PNG that
produce nonedible fruits with massive seeds. These wild species
include: _M. maclayi, M. balbisiana, M. acuminata_ (with subspecies
_banksii_), _M. schizocarpa, M. peekelii_ (with subspecies _angustigemma_), _M.
boman, M. lolodensis_ and _M. ingens_ (Sharrock 1989).

**Banana collecting expeditions to PNG**

In 1970, collecting trips were made to many parts of the country and
some 800 accessions of bananas were assembled at the University of
Technology (Unitech) in Lae (King and Bull 1984). The collection
included farmer landraces as well as six wild types. In 1986-1987, a
Japanese mission made two collecting trips around the country and
collected 52 accessions. Between 1988 and 1989, four collecting
expeditions were undertaken by the International Plant Genetic
Resources Institute (IPGRI) and the Queensland Department of
Primary Industries (QDPI) with assistance from the International
Network for the Improvement of Bananas and Plantains (INIBAP) in
collaboration with PNG Department of Agriculture and Livestock. A
total of 264 accessions were collected during these trips. The latest
collecting trip was taken in 1999 by the NARI staff under the World
Bank Drought and Frost project to collect any bananas that were
surviving throughout the El Niño drought. A total of 26 accessions
were collected from the highlands region and the Central Province.

**Banana germplasm collections**

The PNG national banana germplasm collection is located at NARI
Dry Lowlands Programme (DLP) site, Laloki. This is a field collection
and currently holds 297 accessions of both the cultivated and wild
bananas. The composition of the national collection is presented in
Table 5.

The conserved materials are being characterised morphologically and
undergoing preliminary assessment for fruit yield, eating quality and
resistance/tolerance to pests, diseases and dry conditions. Selections
for dry condition tolerance and good eating qualities are multiplied
on-station and distributed to small farmers on request. Many
subsidy farmers along river basins outside Port Moresby are growing diploid cultivars that originated from Morobe, Madang and other provinces because of their good eating qualities. NARI also maintains small working collections at the NARI Wet-lowlands Island site, Keravat (<70 accessions), Wet-lowlands Mainland site, Bubia (>20 accessions) and Highlands site, Aiyura (26 accessions).

**Improved banana breeding lines**

NARI, Laloki collaborated with QDPI Mareeba in a Banana Sigatoka Resistant Variety study conducted in 1999. The 14 FHIA hybrids and some common cultivars known to be resistant to sigatoka disease were tested at Laloki during the 1999-2000 growing season. The study showed that nine breeding lines/cultivars out of 14 were highly resistant to sigatoka disease. The highly resistant hybrids that yielded over 20 kg/bunch were FHIA-25, FHIA-03 and FHIA-17. The lines/cultivars that produced around 16-19 kg/bunch and are also highly resistant to sigatoka disease were FHIA-18, FHIA-02, FHIA-23, Pisang Ceylan and SH-3436. Taste panel was carried out on all the lines/cultivars as dessert bananas. Cultivars SH-3436 and Pisang Ceylan were recorded as highly liked by the tasters. The lines that were susceptible to sigatoka disease were SH-3640, Musa acuminata banksii and Pisang Berlin. Materials for SH-3436 and Pisang Ceylan are being multiplied for distribution to farmers.

**Opportunities and thrusts**

There is potential for PNG to develop its banana industry, especially the cooking bananas for its domestic market. Prices for bananas in the urban markets throughout the country are very high because of limited production. General observation showed that the current subsistence production does not meet the market demands in urban areas. Once the industry is established, this would encourage more farmers to grow

---

**Table 3.** Composition of PNG national banana germplasm collection as of October 2002.

<table>
<thead>
<tr>
<th>Genomes</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diploid (AA)</td>
<td>116</td>
</tr>
<tr>
<td>Triploid (AAA, ABB, AAB)</td>
<td>147</td>
</tr>
<tr>
<td>Tetraploid (AAAA, AABB, AAAB)</td>
<td>6</td>
</tr>
<tr>
<td>Wild spp.</td>
<td>6</td>
</tr>
<tr>
<td>Others (AS, AAT, BB, AB)</td>
<td>8</td>
</tr>
<tr>
<td>Breeding Line FHIA types</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>297</strong></td>
</tr>
</tbody>
</table>

---
and sell the crop thus reducing the price of bananas sold in the urban markets.

The potential for dessert bananas for the domestic market is also high. The quantity produced at the moment is minimal because of uncertain markets and lack of information on the demand by urban consumers. Lack of market infrastructure throughout the country has hindered the supply of bananas from rural areas to the urban markets. Opportunities exist for the government to develop feeder roads and improve the existing road network throughout the country, to alleviate the problem of accessibility. Proper cold storage depots for fresh produce need to be established in main centres in the country to assist the farmers with their produce.

**Proposed areas of collaborations**

There may be many areas for collaboration under the Network. The two areas where PNG as a subsistence producer of bananas would like to see established is the postharvest and downstream processing and the plant protection area.

Banana skipper, banana leaf scab and fruit fly may not pose serious threat to banana production at the moment, but if production increases through monocropping, economic yield losses will certainly be experienced.

Banana diseases may not cause economic yield reduction at the moment, but once the production acreage increases, diseases such as the leaf spot complex would become a serious problem. Some concerns have been raised by the Research and Quarantine authorities in PNG, regarding the spread of the fusarium wilt from the border area of Sandaun Province to the rest of the country and the introduction and spread of banana bacterial wilt. Collaboration in research in the area of banana diseases would be of great benefit to PNG.

The appropriate technology and skills in postharvest handling and downstream processing of bananas into other food products may have been researched but not developed in PNG. Collaborative research in these areas would be of great benefit to the country.

**References**


Present status of banana cultivation in Sri Lanka

Chandrasiri Kudagamage*

Introduction

The total extent of land under fruit cultivation in Sri Lanka is about 90,000 ha and about 50 different fruit crops are found. Banana is the main fruit crop grown year-round throughout the country. The total fruit production of the country in 1999 was about 640,000 tonnes, in which banana constituted 46%. Annual per capita fruit consumption in Sri Lanka ranges between 21.8 kg to 28 kg and banana is the major fruit crop consumed.

Extent of production and productivity

There is gradual increase in the area cultivated with banana during the last 10 years. However, the production has declined slightly. The productivity remained more or less static around 8 tonnes per hectare (Table 1).

Table 1. Area, production and mean yield of banana.

<table>
<thead>
<tr>
<th>Year</th>
<th>Area (t)</th>
<th>Production (t)</th>
<th>Mean yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>36 699</td>
<td>385 944</td>
<td>10.516</td>
</tr>
<tr>
<td>1991</td>
<td>38 222</td>
<td>371 664</td>
<td>9.724</td>
</tr>
<tr>
<td>1992</td>
<td>37 869</td>
<td>377 280</td>
<td>9.963</td>
</tr>
<tr>
<td>1993</td>
<td>51 277</td>
<td>420 048</td>
<td>8.192</td>
</tr>
<tr>
<td>1994</td>
<td>51 900</td>
<td>509 436</td>
<td>9.816</td>
</tr>
<tr>
<td>1995</td>
<td>50 488</td>
<td>463 632</td>
<td>9.183</td>
</tr>
<tr>
<td>1996</td>
<td>46 665</td>
<td>412 764</td>
<td>8.845</td>
</tr>
<tr>
<td>1997</td>
<td>47 406</td>
<td>404 820</td>
<td>8.539</td>
</tr>
<tr>
<td>1998</td>
<td>47 119</td>
<td>384 864</td>
<td>8.168</td>
</tr>
<tr>
<td>1999</td>
<td>48 075</td>
<td>397 272</td>
<td>8.264</td>
</tr>
<tr>
<td>2000</td>
<td>48 686</td>
<td>403 404</td>
<td>8.286</td>
</tr>
</tbody>
</table>

Banana is grown all over the island except in higher elevation. Kurunegala is the major producing district, which attributes to 20%.

*Director, HORDI, Gannoruwa, Peradeniya, Sri Lanka.
to national production. The other important districts in terms of their production are Rathnapura, Kegalle, Monaragala and Gampaha (Table 2).

Table 2. Area and production of banana in different districts in 1999.

<table>
<thead>
<tr>
<th>District</th>
<th>Area (ha)</th>
<th>Production (000 bunches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombo</td>
<td>971</td>
<td>767</td>
</tr>
<tr>
<td>Gampaha</td>
<td>3 836</td>
<td>3 086</td>
</tr>
<tr>
<td>Kalutara</td>
<td>1 534</td>
<td>1 466</td>
</tr>
<tr>
<td>Kandy</td>
<td>2 564</td>
<td>1 143</td>
</tr>
<tr>
<td>Matale</td>
<td>2 091</td>
<td>1 274</td>
</tr>
<tr>
<td>Nuwar-Eliya</td>
<td>1 006</td>
<td>679</td>
</tr>
<tr>
<td>Galle</td>
<td>1 301</td>
<td>732</td>
</tr>
<tr>
<td>Mataara</td>
<td>1 479</td>
<td>1 412</td>
</tr>
<tr>
<td>Hambantota</td>
<td>2 602</td>
<td>2 015</td>
</tr>
<tr>
<td>Jaffna</td>
<td>528</td>
<td>557</td>
</tr>
<tr>
<td>Kilinochchi</td>
<td>182</td>
<td>135</td>
</tr>
<tr>
<td>Mannar</td>
<td>93</td>
<td>57</td>
</tr>
<tr>
<td>Vavuniya</td>
<td>58</td>
<td>50</td>
</tr>
<tr>
<td>Mullativu</td>
<td>196</td>
<td>146</td>
</tr>
<tr>
<td>Batticaloa</td>
<td>473</td>
<td>246</td>
</tr>
<tr>
<td>Ampara</td>
<td>1 450</td>
<td>1 233</td>
</tr>
<tr>
<td>Trincomalee</td>
<td>290</td>
<td>135</td>
</tr>
<tr>
<td>Kurunegala</td>
<td>9 531</td>
<td>6 614</td>
</tr>
<tr>
<td>Puttalam</td>
<td>1 654</td>
<td>558</td>
</tr>
<tr>
<td>Anuradhapura</td>
<td>9 38</td>
<td>544</td>
</tr>
<tr>
<td>Polonnaruwa</td>
<td>9 53</td>
<td>511</td>
</tr>
<tr>
<td>Badulla</td>
<td>1 622</td>
<td>992</td>
</tr>
<tr>
<td>Moneragala</td>
<td>3 736</td>
<td>2 492</td>
</tr>
<tr>
<td>Ratnapura</td>
<td>4 707</td>
<td>3 573</td>
</tr>
<tr>
<td>Kegalle</td>
<td>3 868</td>
<td>2 541</td>
</tr>
<tr>
<td>Mahaweli'H'</td>
<td>412</td>
<td>148</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>48 075</td>
<td>33 106</td>
</tr>
</tbody>
</table>

Source: Census & Statistics

Banana is available throughout the year. However, highest supply is observed during June and the lowest in December. Hence, prices are low in June and high in January and February (Figure 1). Prices are also high in April due to high demand during the festival season.

Consumption and trade

The consumption of banana is higher than the other fruits. The proportion of consumption of banana to total expenditure on food was 0.16% per household per month. The consumption of banana has not changed significantly over the years. It was 0.13 g/day in 1973, 0.15 g/day in 1986 and 0.12 g/day in 1990/91. The highest
consumption was observed in urban sectors with an average of 7.6 g/day and the rural sector consumption was 3.90 g/day. The consumption among the income group above Rs 3001 (US$30) is higher than average consumption rate (Table 3 and 4).

Table 3. Annual per capita consumption of banana/annum by sector (unit: no.).

<table>
<thead>
<tr>
<th>Sector</th>
<th>Urban</th>
<th>Rural</th>
<th>Estate</th>
<th>All sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978/79</td>
<td>71.50</td>
<td>37.40</td>
<td>35.70</td>
<td>45.10</td>
</tr>
<tr>
<td>1981/82</td>
<td>70.80</td>
<td>42.00</td>
<td>40.80</td>
<td>48.00</td>
</tr>
<tr>
<td>1986/87</td>
<td>91.20</td>
<td>46.80</td>
<td>32.40</td>
<td>54.00</td>
</tr>
</tbody>
</table>

The private sector plays a dominant role in banana marketing. The role of government in banana marketing is negligible. Generally, collectors go to the producing areas once a week using their own or hired vehicles with one or two labourers to collect the produce. The collectors sell the banana to wholesalers. The wholesalers get 10% commission on the sales. The wholesalers sell them to retailers who in turn sell them to consumers.

There is a huge demand for banana in the international market. Sri Lanka exports banana mainly to Korea, Maldives, Middle East, Switzerland, United Kingdom and Germany. The export growth does not seem to be stable and small in quantity and value (Table 5).
Table 4. Annual per capita consumption of banana by income group and sector (1986/87).

<table>
<thead>
<tr>
<th>Income group (Rs)</th>
<th>Urban</th>
<th>Rural</th>
<th>Estate</th>
<th>All sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 100</td>
<td>114.00</td>
<td>22.8</td>
<td>-</td>
<td>43.20</td>
</tr>
<tr>
<td>101 – 102</td>
<td>170.40</td>
<td>51.60</td>
<td>-</td>
<td>92.40</td>
</tr>
<tr>
<td>201 – 200</td>
<td>84.00</td>
<td>16.80</td>
<td>21.60</td>
<td>24.00</td>
</tr>
<tr>
<td>401 – 6</td>
<td>90.00</td>
<td>16.80</td>
<td>4.80</td>
<td>20.40</td>
</tr>
<tr>
<td>601 – 800</td>
<td>84.00</td>
<td>16.80</td>
<td>9.60</td>
<td>21.60</td>
</tr>
<tr>
<td>801 – 1000</td>
<td>28.80</td>
<td>25.20</td>
<td>33.60</td>
<td>26.40</td>
</tr>
<tr>
<td>1001 – 1500</td>
<td>51.60</td>
<td>24.00</td>
<td>30.00</td>
<td>27.60</td>
</tr>
<tr>
<td>1501 – 2000</td>
<td>45.60</td>
<td>33.60</td>
<td>34.80</td>
<td>36.00</td>
</tr>
<tr>
<td>2001 – 3000</td>
<td>58.80</td>
<td>52.80</td>
<td>30.00</td>
<td>52.80</td>
</tr>
<tr>
<td>3001 – 5000</td>
<td>109.20</td>
<td>80.40</td>
<td>52.80</td>
<td>85.20</td>
</tr>
<tr>
<td>5001 – 10 000</td>
<td>133.20</td>
<td>106.80</td>
<td>129.60</td>
<td>118.80</td>
</tr>
<tr>
<td>Over 10 000</td>
<td>180.00</td>
<td>109.20</td>
<td>34.80</td>
<td>147.60</td>
</tr>
<tr>
<td>Overall Ave.</td>
<td>91.20</td>
<td>46.80</td>
<td>32.40</td>
<td>54.00</td>
</tr>
</tbody>
</table>

Table 5. Quantity and value of banana exports in different years.

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (kgs)</th>
<th>Value (Rs)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>53 836</td>
<td>1 670 657</td>
</tr>
<tr>
<td>1992</td>
<td>2 741</td>
<td>158 935</td>
</tr>
<tr>
<td>1993</td>
<td>4 335</td>
<td>952 943</td>
</tr>
<tr>
<td>1994</td>
<td>4 049</td>
<td>823 004</td>
</tr>
<tr>
<td>1995</td>
<td>24 378</td>
<td>4 399 711</td>
</tr>
<tr>
<td>1996</td>
<td>21 794</td>
<td>3 290 171</td>
</tr>
<tr>
<td>1997</td>
<td>2 787</td>
<td>354 776</td>
</tr>
<tr>
<td>1998</td>
<td>2 482</td>
<td>120 239</td>
</tr>
<tr>
<td>1999</td>
<td>1 250</td>
<td>232 000</td>
</tr>
<tr>
<td>2000</td>
<td>2 756</td>
<td>677 365</td>
</tr>
<tr>
<td>2001</td>
<td>35 933</td>
<td>2 169 000</td>
</tr>
</tbody>
</table>

Source: Sri Lanka Custom.
*(US$1=Rs96)

Production constraints

There are several factors contributing to the low productivity of banana in Sri Lanka. Lack of high-yielding varieties, prevalence of pest and diseases, rainfed cultivation, adoption of low plant density and high postharvest losses are some of the production constraints of banana cultivation.
Pest and diseases

There are many fungal and viral diseases affecting banana. Among the diseases, virus diseases of banana cause considerable damage to the fruit quality and banana yield. The important virus diseases are Banana Bract Mosaic Virus (BBrMV), Banana Streak Virus (BSV), Banana Bunchy Top Virus (BBTV) and Banana Mosaic Virus (BMV). Results of a survey (Ariyaratne and Liyanage 2002) showed that 82% of Embul banana is infected with BBTV and 59% with BSV. The incidence of BSV is low. The incidence of BBTV is low in areas of high elevations. The disease incidence is high in areas with high temperature and sunny conditions.

During the later part of 1998 and first quarter of 1999, severe infestation of fruit flies in ripe banana was observed in some parts of the country. The most predominant fruit fly species were Bactocera kandiensis and B. dorsalis. Fruits more than 90 days old showed significantly higher infestation than green banana (less than 75 days old) (Ekanayake et al. 2002).

An internal discoloration in fruits of banana is recorded from many parts of the country. The discoloration seems to be initiated at the nipple end of the fruit and develop towards the stalk end through vascular bundle. The browning discoloration extends up to outer most tissues of the fruits but not to the peel. A pathogen is not associated with this disorder but is suspected to be induced by nutritional/physiological factors (Weerasinghe et al. 2001).

Improved crop management technologies

Non-adoption of improved crop management technologies such as high plant density, irrigation and proper fertilizer management have resulted to poor yield of banana.

The usual plant density used by the farmers is around 1000 plants per hectare, giving a yield of 10-15 tonnes per hectare. Banana farmers do not follow proper nutrient management. Banana has high demand of potassium and farmers use more nitrogen when the crop is fertilized, resulting in nutrient imbalance (Weerasinghe and Premalal 2002).

Postharvest losses

Banana industry in Sri Lanka is predominantly small farmer based, catering mainly to domestic market. The postharvest losses of banana account for about 20%. This is mainly due to the delicate nature of the fruit when it ripens and lack of suitable infrastructures for transport.
from production points to consumers. Very few processed products are marketed in Sri Lanka, primarily due to the difficulty in retaining the characteristic colour, flavour and the tenure during processing.

**Research and development**

R&D programme is focused on increasing productivity and solving the field problems.

**Varietal Improvement**

Varieties obtained from International *Musa* Testing Programme (IMTP) of INIBAP were evaluated for their yield and other agronomic characters. Two varieties were identified as superior and recommended for cultivation (DOA 2001). Yield data of these varieties and a local selection is given in Table 6.

- **Kandula** This Cavendish type banana variety can be used both as a dessert type and cooking purpose. It is an early-bearing variety with high yield.
- **Pulathesi (FHIA-03)** A high-yielding Cavendish variety suitable as a cooking banana. It has a robust and semi-dwarf pseudostem and hence can resist wind damage. It showed resistance to black sigatoka.
- **Prasad** It is a cooking type of banana with high yield and adaptability to both dry and wet zones.

**Table 6.** Yield performance of three consecutive crops of the three candidate varieties.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Bunch wt (kg)</th>
<th>Yield (t/ha)</th>
<th>Bunch wt (kg)</th>
<th>Yield (t/ha)</th>
<th>Bunch wt (kg)</th>
<th>Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother crop</strong></td>
<td></td>
<td></td>
<td><strong>1st ratoon</strong></td>
<td></td>
<td><strong>2nd ratoon</strong></td>
<td></td>
</tr>
<tr>
<td>Angunakolapelessa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nadee</td>
<td>13.3</td>
<td>14.6</td>
<td>15.2</td>
<td>16.7</td>
<td>15</td>
<td>16.5</td>
</tr>
<tr>
<td>Kandula</td>
<td>25.5</td>
<td>28.0</td>
<td>21.5</td>
<td>23.7</td>
<td>25.8</td>
<td>28.4</td>
</tr>
<tr>
<td>Pulathesi</td>
<td>26.3</td>
<td>28.9</td>
<td>27.1</td>
<td>29.8</td>
<td>24.3</td>
<td>26.7</td>
</tr>
<tr>
<td>Prasad</td>
<td>13.5</td>
<td>14.9</td>
<td>14.2</td>
<td>15.6</td>
<td>15.0</td>
<td>16.5</td>
</tr>
<tr>
<td>Mahaiiluppallama</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prasad</td>
<td>13.2</td>
<td>14.5</td>
<td>14.5</td>
<td>15.9</td>
<td>15.3</td>
<td>16.8</td>
</tr>
</tbody>
</table>

*Each figure is mean of nine bunches*
Development of virus-free banana foundation stocks

There are four main virus diseases of banana in Sri Lanka. Primary source of viruses is the vegetative planting material obtained from infected plants. At present, sucker production of banana is mainly done through conventional methods using vegetatively produced suckers. Hence, a programme was initiated to produce virus-free foundation stock of banana. The programme constitutes the following steps as described by Dassanyake and Rathnabarathi 2002.

1. Apparently virus-free high-yielding plants are collected from home gardens. Additionally, planting materials are also collected from researchers and importers of planting material.

2. Collected plants are maintained in an aphid-proof planthouse.

3. One month after establishment, indexing is carried out for the four viruses using Enzyme Linked Immuno Solvent Assay (ELISA) techniques. ELISA negative samples for the four viruses were once again indexed by ELISA. Polymerase Chain Reaction (PCR) tests were then carried out for the final ELISA negative samples.

4. Multiplication of healthy banana through conventional method under aphid-proof greenhouse conditions.

5. Issue of healthy planting material for rapid multiplication to tissue culture laboratories.

6. Random indexing of the tissue culture propagation.

High density planting

The productivity of banana is high at high plant densities (Table 7). The fruit and bunch characters are not affected by high plant density. In addition, high plant density results in early harvesting. The cost of production of per kg of banana is low under this system.

Table 7. Performance of dessert variety under two population densities.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>High density (3333 plants/ha)</th>
<th>Standard density (1111 plants/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to flowering</td>
<td>249.0</td>
<td>296.0</td>
</tr>
<tr>
<td>Bunch weight (kg)</td>
<td>14.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Number of hands</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Fruit weight (kg)</td>
<td>98.2</td>
<td>99.0</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>39.4</td>
<td>16.4</td>
</tr>
</tbody>
</table>

Adopted from S Weerasinghe 2000
Postharvest loss reduction and value addition

The product quality of banana can be enhanced by bunch covering. Bunch weight could be increased by 18-23% while promoting the appearance of fruit when bunches are covered with suitable material. Woven polysac bags were identified as the most economical type of bagging material (Weerasinghe and Ruvanpathirana 2002).

Production of banana fruit leather is a means of utilizing small and blemished fruits that are unmarketable. Variety Anamalu showed the best performance for banana fruit leather production in terms of overall acceptance as well as other sensory properties (Ekanayake and Bandara 2002).

Research thrusts and collaboration

R&D activities are planned to increase the productivity.

1. Development of high-yielding, high quality varieties through varietal introduction and evaluation of local germplasm

2. Development of healthy planting material through virus indexing and tissue culture.

3. Development of environmentally friendly techniques for management of diseases such as sigatoka, fusarium wilt and viral diseases. Emphasis will be placed on development of biocontrol methods for fusarium wilt.

4. Development of improved crop management techniques such as high plant density and micro-irrigation techniques.

5. Reduction of postharvest losses and development of value-added products to reduce the loss during the glut.

There had been a lot of collaborative activities with INIBAP in the past which will be strengthened in the future. Emphasis will be placed on the following areas for future collaboration:

1. Training
   - Training young scientists on micro-propagation and other molecular techniques used in crop improvement
   - Training on detection of viruses through serological and molecular techniques
   - Training in biocontrol methods used for disease management
2. Exchange of germplasm
   • High quality, high-yielding varieties will be exchanged with
     the objective of increasing quality and yield of local varieties

3. Exchange of information
   • Information on new technological innovations will be
     exchanged using print and electronic media

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Banana in Thailand

Prasert Anupunt*

Introduction

As it originated in Southeast Asia, bananas are capable of growing in a wide range of environmental conditions favourable for the humid and hot climates. As a non-seasonal crop, year round production is possible if cultural management is appropriate. Hence, crop productivity can be controlled to serve the market all throughout the year.

Banana plays a major role in food security and income generation for millions of the region’s rural poor. It is an important source of energy and in addition, it is high in a number of important vitamins and minerals, providing a nutritious staple food. Apart from fresh consumption and various processing product uses, the other parts of banana, including pseudostem and leaf, are also utilized in many Thai cultural and traditional activities. Mostly, the fruit produce is served for domestic consumption. A number of fresh fruits and processed products are also exported to various countries with the value of approximately 100 million Thai baht (US$2.3 million) each year. Meanwhile, the crop has developed into a major Thai industry.

Industry status

Planting area and production volume

Bananas are cultivated widely by smallholders in many parts of Thailand ranging from a small number of plants to orchards of ten hectares.

Table 1. Area and production volume of banana in Thailand in 2000.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Area (000 ha)</th>
<th>Yield (t)</th>
<th>Yield/area (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bearing</td>
<td>Non-bearing</td>
<td>Total</td>
</tr>
<tr>
<td>Kluai Hom</td>
<td>10 040</td>
<td>3 763</td>
<td>13 803</td>
</tr>
<tr>
<td>Kluai Khai</td>
<td>14 575</td>
<td>3 103</td>
<td>17 672</td>
</tr>
<tr>
<td>Kluai Namwa</td>
<td>110 919</td>
<td>20 734</td>
<td>131 653</td>
</tr>
</tbody>
</table>

Source: Department of Agriculture Extension, 2000.

*Director, HRI, Department of Agriculture, Chatuchak, Bangkok 10900 Thailand.
Major cultivars

There are a number of banana varieties grown throughout the country. Due to consumer preference, adaptability, yield and tolerance to pests, three varieties, viz. Kluai Hom, K. Khai (Pisang Mas) and K. Namwa (Pisang Awak), are cultivated commercially, the potential production areas of which are different.

Kluai Hom (AAA group). K. Hom, in particular K. Hom Thong (Gros Michel), became a popular clone in both export and domestic markets for fresh consumption. Ripe fruits are sweet and have unique flavour and the fruit size is rather big and long, compared to K. Namwa and K. Khai. The plant is about 2.5 meters in height and the duration from planting to harvesting is about 10-11 months. Aside from K. Hom Thong, the other clones, which are commercially important, include K. Hom Khieo (Lacatan) and K. Hom Khom (Dwarf Cavendish), among others. The production zones of K. Hom are located in some provinces at the southern part and the central lowland regions, i.e. Chumporn, Songkhla, Ranong, Petchburi, Nakornpathom, Nonthaburi and Pathum Thani.

Kluai Khai (AA group). It has delicious, good taste and flavour and the fruits are famed for fresh consumption. The plants, however, are quite susceptible to yellow sigatoka. The plants and the bunch are rather small and short in size compared to other bananas. The crop-growing areas are restricted in the lower northern and the upper-southern regions, i.e. Kamphaengpet, Nakornsawan, Tak, Sukhothai, Petchburi and Prachuabkhirikhan.

Kluai Namwa (ABB group). It is the most popular banana in Thailand. This banana is easily grown and widely adapted to several areas in the country. In addition, all parts of the plant can be utilised. The fruits are consumed fresh as desserts or cooked. Pseudostems are used in social and religious functions and for feeding pigs in the rural areas. Leaves are also utilized as wrapping material and in art works. The duration from planting to harvesting lasts about 14 months. The plant height ranges from two to five meters. There are many clones, namely: K. Namwa, K. Namwa Daeng, K. Namwa Luang, K. Namwa Khao, K. Namwa Khom and K. Namwa Ngeon. The production provinces of K. Namwa are spread from the upper southern region, the central plain and the lower-northern region, i.e. Chumporn namely, Petchburi, Rachburi, Nakornpathom, Prathumthani, Phitsanulok and Sukhothai.
Consumption, utilisation and trade

Banana is mainly used as food, either fresh, cooked or processed. About 20% of total production is processed. The common products derived from banana are chips, figs, dehydrated and dried, paste, jam, flour, candy and canned.

The fruits are mostly produced for domestic consumption. Only a small volume is exported. There are several ways of product distribution from orchards to consumers such as local markets, wholesale markets and supermarkets.

Exporters and middlemen recently pay a great attention to banana from Thailand as they deal with the growers and signed contract in advance for the products. Such event expresses a positive sign on an increase in export volume. Nevertheless, the export quantities of both fresh fruits and processing products are still variable due to marketing situation and the fluctuation of yield.

Table 2. Volume and value of fresh banana fruits exported from Thailand in 2001.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Volume (t)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>THB (million)</td>
</tr>
<tr>
<td>Kluai Hom</td>
<td>1520</td>
<td>41.5</td>
</tr>
<tr>
<td>Kluai Khai</td>
<td>3533</td>
<td>48.4</td>
</tr>
<tr>
<td>Others</td>
<td>470</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Source: Department of Customs

Table 3. Volume and value of banana products exported from Thailand in 2001.

<table>
<thead>
<tr>
<th>Product</th>
<th>Volume (t)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>THB (million)</td>
</tr>
<tr>
<td>1. Product in gas filled package</td>
<td>198</td>
<td>6.7</td>
</tr>
<tr>
<td>2. Dehydrated banana</td>
<td>136</td>
<td>8.7</td>
</tr>
<tr>
<td>3. Banana product with sugar</td>
<td>237</td>
<td>32.4</td>
</tr>
</tbody>
</table>

Source: Department of Customs.

For fresh banana, a large number of K. Khai are exported to Canada, China and Hong Kong while K. Hom goes to Japan, Hong Kong, Canada and Sweden. The processed products are mostly exported to the USA, Malaysia, Italy and Japan.
Production constraints

Production practice

In Thailand, banana is mainly grown under rainfed condition and poor cultural practice management. In addition, most growers are smallholder producers with limited knowledge on production technology. Hence, the major problems affecting banana production are:
- low yield;
- inconsistent quality either in fruit shape, size or characteristics;
- lack of high yielding varieties;
- narrow fruit bearing season leading to oversupply and low prices;
- unsuitable handling, packaging and transportation.

Environmental factors

As mentioned earlier, most orchards are established under rainfed cultivation system. As such, plants have to be grown at the same period resulting to overflowing of products into the market at nearly the same time causing an oversupply. In contrast, in some periods there are no products available. This circumstance causes disadvantage on export promotion.

Current banana R&D activities, programmes and institutions involved

Banana research is mostly undertaken by government agencies. There are many institutes involved such as Department of Agriculture, Department of Agriculture Extension, Kasetsart University, Chulalongkorn University, Maejo University.

As banana is not the main export crop of the country, there are no immense R&D plans. Moreover, the financial support on research, production improvement and marketing system are very limited. Nevertheless, over the past few years, banana R&D in Thailand are still undertaken on some areas as follows:

Germplasm collection and conservation

About 175 accessions have been collected and conserved under care of Department of Agriculture, Department of Agriculture Extension and Kasetsart University. Most of these have been characterised on morphology and taxonomy. Some have been used for breeding programmes.
Production system

R&D on production systems are aimed to improve yield and qualities. Investigation so far, has been carried out on variety improvement and cultural practices such as:

- Development of production technology for improving growth, yield and qualities of Grande Naine;
- Effect of sucker size on growth of Grande Naine;
- Sucker-dividing effect on growth of K. Hom, K. Khai and K. Namwa;
- Effect of media on Grande Naine seedling growth;
- Effect of some foliar fertilizers on growth of Grande Naine seedling;
- Study on the growth of inflorescence and fruit of K. Hom Khom
- Selection of saline-tolerant varieties through tissue culture techniques;
- Effect of number of genomes on propagation via tissue culture methods;
- Increasing number of chromosomes of K. Leb Mu Nang using colchicine under aseptic condition;
- Banana improvement through tissue culture and gamma radiation;
- Conservation of abaca (*Musa textilis* Nee.) under aseptic condition;
- Study on the possibility of conservation of banana germplasm with liquid N.

Postharvest

As oversupply of production is a serious problem for growers every year, most research on postharvest has been emphasized on processing and utilising banana in various forms. The following are some areas of research over the past few years:

- Study on appropriate technology for producing banana wine and liqueur;
- The use of banana and its by-product in cosmetic industry
- Extraction of tannin from banana rind;
- Development of drying banana by using solar energy in combination with electrical energy;
- Producing banana flour from fruit and other parts;
- Production and utilisation of banana puree;
- Comparison of drying methods for dried banana production;
- Study on banana catsup production and preservation;
- Investigation on the methods for delayed ripening of K. Namwa
- Shipment trial for sea transportation of K. Khai to Denmark

**Integrated pest management (IPM)**

There is no immense research on IPM of banana. Nevertheless, there is a corporation between Japan and Thai cooperatives in producing either organic or chemical residue-free banana. Meanwhile, the market of this particular productivity is restricted to Japan and some European markets.

**Opportunities and thrust**

Thailand is fortunate for not having serious natural disaster and disease problems. Due to the localisation and climate, bananas can be grown throughout the country. In addition, some Thai bananas, such as K. Hom Thong and K. Khai have a unique flavor.

**Proposed areas of collaboration**

Although Thailand has no serious problems of viral, bacterial and fungal infection, other fields of work and problem related to improve banana production are still awaited for development and solution. Following are the areas where research collaboration and training are needed:

- Breeding and crop improvement via conventional, tissue-culture and genetic-engineering techniques;
- Production technology;
- Germplasm conservation both *in vivo* and *in vitro*;
- Exchange of germplasm;
- Tissue-culture and disease-free planting-material propagation; and
- Postharvest technology.
Update on banana R&D in Vietnam

Ho Huu Nhi

General production status

Ranging between $8^\circ$ and $23^\circ23'$N Vietnam has diverse geographical features. In the south, it is tropical with two distinct seasons (wet and dry) while in the north there is a subtropical climate with four seasons: spring, summer, autumn and winter. As banana can widely adapt to different climatic conditions, they have long been grown in all the eight agro-ecological regions in the country. In 1998, Mekong River Delta ranks first in terms of total banana growing area and fruit production, followed by Red River Delta (Table 1).

**Table 1.** Banana production in different regions of Vietnam (1998).

<table>
<thead>
<tr>
<th>Region</th>
<th>Total growing area (ha)</th>
<th>Average yield (t/ha)</th>
<th>Total production (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red River Delta</td>
<td>14 505</td>
<td>18.27</td>
<td>264 964</td>
</tr>
<tr>
<td>North East</td>
<td>9 292</td>
<td>15.59</td>
<td>144 891</td>
</tr>
<tr>
<td>North West</td>
<td>2 540</td>
<td>12.26</td>
<td>31 142</td>
</tr>
<tr>
<td>North Central Coast</td>
<td>13 567</td>
<td>4.63</td>
<td>62 844</td>
</tr>
<tr>
<td>South Central Coast</td>
<td>9 052</td>
<td>13.08</td>
<td>118 371</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>2 592</td>
<td>8.24</td>
<td>21 360</td>
</tr>
<tr>
<td>South East</td>
<td>9 700</td>
<td>27.77</td>
<td>269 364</td>
</tr>
<tr>
<td>Mekong River Delta</td>
<td>34 884</td>
<td>11.53</td>
<td>402 253</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>96 132</strong></td>
<td><strong>11.53</strong></td>
<td><strong>1 315 189</strong></td>
</tr>
</tbody>
</table>

The results in Table 1 show that the total banana growing area in Vietnam was 96 132 ha in 1998 giving total production of 1 315 189 tonnes. At present, farmers are using local varieties with different genotypes (Table 2).

**Table 2.** Set of popular banana varieties in Vietnam.

<table>
<thead>
<tr>
<th>Cultivars</th>
<th>Genotype</th>
<th>Location</th>
<th>Bunch weight (kg)</th>
<th>Growth duration (months)</th>
<th>Fruit quality, utilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chuoi Ngu</td>
<td>AA</td>
<td>Red River Delta</td>
<td>8-10</td>
<td>12</td>
<td>Sweet, aromatic, desert</td>
</tr>
<tr>
<td>Chuoi Tien</td>
<td>AA</td>
<td>Red River Delta</td>
<td>6-8</td>
<td>12</td>
<td>Worship, donation</td>
</tr>
<tr>
<td>Chuoi Tieu</td>
<td>AAA</td>
<td>All regions</td>
<td>20-25</td>
<td>14-16</td>
<td>Dessert, local and export</td>
</tr>
<tr>
<td>Chuoi Bom</td>
<td>AAB</td>
<td>Central highlands</td>
<td>8-10</td>
<td>9-10</td>
<td>Dessert, dried</td>
</tr>
<tr>
<td>Chuoi Tay</td>
<td>ABB</td>
<td>All regions</td>
<td>18-20</td>
<td>12-14</td>
<td>Dessert, collapsed</td>
</tr>
</tbody>
</table>

*Head, Agro-biotechnology Department, VASI, Hanoi, Vietnam.
In each ecological region, there are main varieties cultivated for different purposes and utilities. Other cultivars such as Chuoi Mat, C. Mit, C. La and C. Man are scattered all over the country, and are used for various purposes: feeding (stem), cake wrapping (leave) and medicine (fruit).

**Banana research**

*Research institutes system*

There is no specialized banana research institute in Vietnam. Moreover, banana has not enjoyed much attention in comparison to other fruits such as mango, litchi and pineapple, and hence researches on banana have been coordinated under a national network. This network comprises many institutions concerned and is under the coordination of Vietnam Agricultural Science Institute (VASI). Its goal is to help scientists concerned in banana research activities and to use most effectively the available inputs. The number of members in the network has changed annually. The following is the list of institutions participating in the network (Table 3).

Table 3. List of the institutions participating in banana researches.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam Agricultural Science Institute (VASI)</td>
<td><em>In vitro</em> conservation, selection, propagation; material exchange; information dissemination and disease study</td>
</tr>
<tr>
<td>Fruit and Vegetable Research Institute</td>
<td>Selection, cultivation technique</td>
</tr>
<tr>
<td>Phu ho Fruit Research Center</td>
<td>Characterization, field conservation</td>
</tr>
<tr>
<td>Plant Protection Institute</td>
<td>Pest and disease study</td>
</tr>
<tr>
<td>Institute of Ecology and Biological Resources</td>
<td>Nematode and weevil borer study</td>
</tr>
<tr>
<td>Long dinh Fruit Research Center</td>
<td>Field conservation, selection; cultivation technology; pest and disease study</td>
</tr>
</tbody>
</table>

Beside the abovementioned institutions, the national companies of fruits and vegetables of Vietnam, agricultural extension organizations and various farmers also take part in banana research activities.

**Genetic resource**

Vietnam is one of the countries, which have a large diversity of banana germplasm. Since 1997, under the framework of the project “Collection, Characterization and Conservation of Indigenous Banana Germplasm in Vietnam” 72 accessions were collected. These are now conserved in VASI, including 63 cultivated and 9 wild accessions (Table 4). All the accessions were evaluated, and their name and synonyms in Southeast Asia defined.
In intensive collaboration with Dr Ramon Valmayor, the former regional coordinator of the INIBAP Asia and the Pacific Network, two wild banana species, *Musa exotica* and *Musella splendidia* were identified. Under the framework of the joint project for establishment of national repository, multiplication/dissemination centers, 35 banana accessions were directly introduced from ITC to VASI in the form of *in vitro* plantlets. These are now being maintained and provide material for IMTP experiments (Table 5).

### Table 4. Vietnamese banana collection conserved in VASI.

<table>
<thead>
<tr>
<th>Group</th>
<th>Accession name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAB</td>
<td>C. Goong, C. Com Chua, C. Tram Nai, C. Cha, C. Sung Bo, C. Voi, C. Xiem Mat</td>
</tr>
<tr>
<td>AB</td>
<td>C. Dong, C. La Ta, C. Nanh Heo, C. Com Lao, C. La Mang Tieu, C. Mit, C. Thom</td>
</tr>
<tr>
<td>ABBB</td>
<td>Chuoi Gao</td>
</tr>
<tr>
<td>BBB</td>
<td>C. Mat, C. Ngu, C. Chua, C. Sap, C. Ngop Dui Duc</td>
</tr>
<tr>
<td>BB</td>
<td>C. Hot Qua Lep, C. Hot</td>
</tr>
</tbody>
</table>

### Table 5. List of banana accessions introduced from ITC to Vietnam.

<table>
<thead>
<tr>
<th>No.</th>
<th>ITC code</th>
<th>Accession name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0312</td>
<td>Pisang Jari</td>
</tr>
<tr>
<td>2</td>
<td>0504</td>
<td>FHIA-01</td>
</tr>
<tr>
<td>3</td>
<td>0505</td>
<td>FHIA-02</td>
</tr>
<tr>
<td>4</td>
<td>0506</td>
<td>FHIA-03</td>
</tr>
<tr>
<td>5</td>
<td>0570</td>
<td>William</td>
</tr>
<tr>
<td>6</td>
<td>0643</td>
<td>Cachaco</td>
</tr>
<tr>
<td>7</td>
<td>0712</td>
<td>AAcv Rose</td>
</tr>
<tr>
<td>8</td>
<td>1122</td>
<td>Gros Michel</td>
</tr>
<tr>
<td>9</td>
<td>1123</td>
<td>Yangambi Km5</td>
</tr>
<tr>
<td>10</td>
<td>1264</td>
<td>FHIA-17</td>
</tr>
<tr>
<td>11</td>
<td>1265</td>
<td>FHIA-23</td>
</tr>
<tr>
<td>12</td>
<td>1282</td>
<td>GCTCV 119</td>
</tr>
<tr>
<td>13</td>
<td>1283</td>
<td>SH-3436-9</td>
</tr>
<tr>
<td>14</td>
<td>1296</td>
<td>TMBx 1378</td>
</tr>
<tr>
<td>15</td>
<td>1297</td>
<td>TMBx 5295-1</td>
</tr>
<tr>
<td>16</td>
<td>1307</td>
<td>SH-3640</td>
</tr>
<tr>
<td>17</td>
<td>1319</td>
<td>FHIA-18</td>
</tr>
<tr>
<td>18</td>
<td>1332</td>
<td>FHIA-21</td>
</tr>
<tr>
<td>19</td>
<td>1344</td>
<td>CRBP 39</td>
</tr>
<tr>
<td>20</td>
<td>1418</td>
<td>FHIA-25</td>
</tr>
<tr>
<td>21</td>
<td>1441</td>
<td>Pisang Ceylan</td>
</tr>
<tr>
<td>22</td>
<td>0320</td>
<td>Paka</td>
</tr>
<tr>
<td>23</td>
<td>0247</td>
<td>Honduras</td>
</tr>
<tr>
<td>24</td>
<td>0249</td>
<td>Calcutta</td>
</tr>
<tr>
<td>25</td>
<td>0649</td>
<td>Foconah</td>
</tr>
<tr>
<td>26</td>
<td>0653</td>
<td>Pisang Mas</td>
</tr>
<tr>
<td>27</td>
<td>1034</td>
<td>Kunnan</td>
</tr>
<tr>
<td>28</td>
<td>1060</td>
<td>Selangor</td>
</tr>
<tr>
<td>29</td>
<td>1120</td>
<td>Tani</td>
</tr>
<tr>
<td>30</td>
<td>1138</td>
<td>Saba</td>
</tr>
<tr>
<td>31</td>
<td>1183</td>
<td>Pisang Lemak Manis</td>
</tr>
<tr>
<td>32</td>
<td>1417</td>
<td>TMBx 15108-6</td>
</tr>
<tr>
<td>33</td>
<td>1437</td>
<td>TMBx 9128-3</td>
</tr>
<tr>
<td>34</td>
<td>1442</td>
<td>GCTCV 106</td>
</tr>
<tr>
<td>35</td>
<td>1443</td>
<td>GCTCV 247</td>
</tr>
</tbody>
</table>
**Varietal improvement and propagation**

In the past years, during evaluation of banana germplasm, Phuho Fruit Plants Research Center has selected two promising varieties, belonging to Cavendish group, VN-064 and VN-065. These varieties have high yield, about 18-20% higher than that of the control. Their fruits are big and bright yellow in color. With their pulp sweet and aromatic, fruits have a high export value. At present, the Center is conducting different experiments to establish a performance model for demonstrating to farmers. Among three accessions, FHIA-01, FHIA-02 and FHIA-03, the accession FHIA-02 gave the highest yield, good growth, but soft and sour fruits which have not met demands for good quality banana.

In vitro mutation was carried out using radioactive rays and chemicals, and achieved visible success. Treatment with Co\textsuperscript{60} rays on C. Tay (ABB) with 20-30 Gy dose in vitro induced new variations. Colchicine was applied on diploid (AA and AB) in vitro and also gave good results. At the concentration of 0.5-0.7%, colchicine produced tetraploid clones at a rate of 9-13%. Some changes can be recognized in these variations such as stem diameter, leaf size and number of stomata. These variants have been used in testing and selecting program for tolerance to *Fusarium*.

**IMTP III**

For obtaining the objectives of the IMTP, identification of new varieties with high yield and good adaptation to local climatic conditions, many Vietnamese banana and 35 ITC varieties have been used in evaluation experiments for disease resistance and agronomic characteristics. The objectives of these experiments include:
- screening varieties for resistance to *Fusarium*
- screening varieties for resistance to leaf spot
- screening varieties for resistance to nematodes

**Propagation**

In the recent years, with valuable supports from the Ministry of Science and Technology, different provincial departments of Science and Technology have established in vitro laboratories for cell and tissue culture with the purpose of recovery and multiplication of fruit tree varieties of high economical values. Therefore application of cell and tissue culture techniques for rapid propagation of banana has achieved significant progress.
Protocol on banana tissue culture propagation was established. It involves the following steps: meristem culture, *in vitro* propagation, rooting, hardening of plantlets and re-establishment in nursery.

Cultivation and plant management techniques have been developed for *in vitro* culture derived plantlets, and have been introduced to farmers. In many areas, farmers get used to using *in vitro* plantlets for production. In 2002, the Ministry of Science and Technology of Vietnam approved a banana multiplication project in order to provide planting materials for Nghe An area where banana starch producing factory is located. As the plan, an amount of 50 000 – 60 000 banana plantlets will be distributed to farmers annually. However, banana multiplication using *in vitro* techniques faces various difficulties, including lack of necessary equipment resulting in low capacity and high production price of plantlets. Farmers therefore use *in vitro* propagated plantlets only when subsidies from the project are provided.

*Pest and disease study*

During the period of 1996-1999, the result of investigation revealed that 17 different pathogens are causing damages on banana in Vietnam, including nine fungi species, three viruses, two bacteria and three nematode species (Table 6).

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Infection site</th>
<th>Occurrence frequency</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fusarium oxysporum f.sp. cubense</em></td>
<td>whole plant</td>
<td>+++</td>
<td>ABB</td>
</tr>
<tr>
<td><em>Mycosphaerella musicola</em> (yellow sigatoka)</td>
<td>leaf</td>
<td>+++</td>
<td>AAA</td>
</tr>
<tr>
<td><em>Mycosphaerella fijiensis</em> (Black sigatoka)</td>
<td>leaf</td>
<td>++</td>
<td>AA</td>
</tr>
<tr>
<td><em>Cordana musae</em></td>
<td>leaf</td>
<td>+++</td>
<td>ABB</td>
</tr>
<tr>
<td><em>Cladosporium musae</em></td>
<td>leaf</td>
<td>++</td>
<td>both</td>
</tr>
<tr>
<td><em>Periconiella musae</em></td>
<td>leaf</td>
<td>+</td>
<td>both</td>
</tr>
<tr>
<td><em>Capnodium spp</em></td>
<td>leaf, fruit</td>
<td>+++</td>
<td>both</td>
</tr>
<tr>
<td><em>Erwinia spp</em></td>
<td>corm</td>
<td>+</td>
<td>AAA</td>
</tr>
<tr>
<td><em>Pseudomonas musae</em></td>
<td>leaf</td>
<td>++</td>
<td>both</td>
</tr>
<tr>
<td><em>Macrophoma musae</em></td>
<td>leaf</td>
<td>++</td>
<td>both</td>
</tr>
<tr>
<td><em>Leptophaerella musarium</em></td>
<td>leaf</td>
<td>+++</td>
<td>both, north</td>
</tr>
<tr>
<td>Banana Bunchy Top Virus (BBTV)</td>
<td>whole plant</td>
<td>++</td>
<td>AA</td>
</tr>
<tr>
<td>Cucumber Mosaic Virus (CMV)</td>
<td>leaf</td>
<td>+</td>
<td>both</td>
</tr>
<tr>
<td>Banana Streak Virus (BSV)</td>
<td>leaf</td>
<td>+</td>
<td>both</td>
</tr>
<tr>
<td>Banana scab moth (Basilepta)</td>
<td>skin young fruit</td>
<td>++</td>
<td>AA</td>
</tr>
<tr>
<td>Banana weevil borer</td>
<td>corm, pseudostem</td>
<td>++</td>
<td>AAA, ABB, highland</td>
</tr>
<tr>
<td>Nematode</td>
<td>root, corm</td>
<td>+</td>
<td>both, highland</td>
</tr>
</tbody>
</table>
The most important diseases found were:

*Fusarium wilt:* This disease occurs in all the ecological regions in the whole country. However, it is more often observed in the south than in the north, and mostly on C.Tay (Pisang Awak, ABB group). It attacks banana plants at 4-6 month of age and at the flowering stage. Fusarium wilt in Vietnam is caused by Foc that belongs to race 1.

*Sigatoka:* This disease spreads at a large scale in the Mekong River Delta in the south. Yellow sigatoka (*Mycosphaerella musicola*) damages banana at a higher rate than black sigatoka (*Mycosphaerella fijiensis*) and is found mainly on Cavendish group (AAA).

Among viruses found on banana in Vietnam, BBTV is the most important one, discovered in all ecological regions and causing heavy damage on Cavendish group.

A joint project entitled “Identification of nematodes resistance and tolerance in Vietnamese *Musa* germplasm for improvement of banana production” between INIBAP and VASI was carried out under the assistance of VVOB and ACIAR. The following activities have been done during the process of the project:

1. **Assessment of the occurrence and distribution of nematodes on wild and cultivated bananas in north and central Vietnam**

Surveys have been carried out in some northern provinces and in the central part of Vietnam as well as in 3 natural habitats in north Vietnam. Some wild banana species [C. Rung (VN1-026), C. Rung Hoa Do (VN1-049) and C. Tay Rung (VN1-051)] and some common cultivars [C. Tieu (AAA), C. Tay (ABB) and C. Hot (BB)] were sampled.

With the exception of *Radopholus similis*, the most important *Musa* nematodes, i.e. *Pratylenchus coffeae*, *Meloidogyne* spp. and *Helicotylenchus multicinctus*, were found on both wild and cultivated bananas. This means that the natural soils of Vietnam are infested with these nematodes and we therefore infer that these species are indigenous to Southeast Asia. *Meloidogyne* spp. seemed to have a negative influence on the growth of banana plants while the effect of *P. coffeae* on *Musa* plant growth was not very clear.

2. **Establishment and maintenance of in vitro nematode cultures**

Eleven *P. coffeae* populations collected from different areas in Vietnam are being maintained *in vitro* on carrot discs to provide for morphological and biological studies. A population of *Meloidogyne* spp. collected from Habac province is being propagated in the roots of
tomato in the greenhouse of VASI.

3. **Assessment of damage and yield loss potential of *P. coffeae* and *Meloidogyne* spp. on banana in the field**

Infection of *Musa* plants with *P. coffeae* did not reduce the plant height and the girth of the pseudostem. The number of standing leaves of the plants infected with *P. coffeae* was lower than that of the control plants for only one of the tested genotypes (Ben Tre (AAA)). Infection of *Musa* plants with *Meloidogyne* spp. on the other hand reduced the plant height, the girth of the pseudostem and the number of standing leaves of the plants. These results indicate that the effect of *Meloidogyne* spp. on *Musa* spp. may often be underrated.

4. **Population dynamics of *P. coffeae* under greenhouse and field conditions**

The reproductive fitness of the population was strongly dependent on temperature and moisture. Cool temperatures during the winter months and flooding due to abundant rainfall during the rainy season slowed the reproduction of the nematodes and could even reduce the nematode population.

5. **Screening of Vietnamese *Musa* germplasm for resistance and/or to *P. coffeae* and *Meloidogyne* spp.**

Twenty-six Vietnamese banana accessions and some references were evaluated for resistance and/or tolerance to *P. coffeae* and *Meloidogyne* spp. under greenhouse conditions. Possible sources of resistance/tolerance to *P. coffeae* were found: the genotypes Yangambi Km 5 (AAA), Tieu Xanh (AAA), Tieu Mien Nam (AA), Gros Michel (AAA), Com Chua (AAB), Com Lua (AA), Man (AAB), Ngu Thoc (AA) and Grande Naine (AAA). No source of resistance to *Meloidogyne* spp. was found. All the tested genotypes were found to be at least as susceptible to *Meloidogyne* spp. as the susceptible reference genotype Grande Naine and the final nematode population in the roots was always much higher than the initial inoculum. The intensity of root galling was less on the genotypes Man, Tay (ABB), Ngu Thoc and Yangambi Km 5.

The host-plant reaction to *Meloidogyne* spp. of eight Vietnamese *Musa* genotypes, as well as the genotypes FHIA-01 (AAAB), FHIA-02 (AAAA) and Yangambi Km 5, was evaluated under field conditions. The genotypes FHIA-01, Ngu Thoc, Tay and Com Lua were found less susceptible to *Meloidogyne* spp. The genotypes FHIA-01, Ben Tre (AAA) and Bom (AAA) were less sensitive to root galling.
6. **Assessment of the occurrence of *Radopholus similis* on banana and other crops in Vietnam**

Three surveys were carried out in Western Highland region (Taynguyen, Gialai and Kontum provinces. Roots of coffee, black pepper, durian, banana, ... were collected. One *R. similis* population is now being maintained on carrot discs for morphological and biological studies.

**Biotechnology**

In recent years, tissue culture techniques have been developed and applied to banana production effectively in the following aspects:

1. Recovery and production of disease-free planting materials

2. A protocol for *in vitro* banana production is completed and used over 32 tissue culture laboratories throughout the country. *In vitro* selection is considered a good way for quick evaluation of the resistance to *Fusarium* of C. Tay.

3. Molecular marker

4. The recently developed molecular technique was applied for effective selection and production of banana varieties

5. Extraction and purification of DNA

6. Analysis and identification of enzyme link markers (for AAA banana group)

7. Use of RADP in identifying genetic diversity of banana germplasm. Through the genomic analysis of 4 genotypes: AA, AAB, AB and BB, 2 different molecular markers have been detected.

8. Establishment of a method for evaluation and diagnosis of BBTV by PCR technique.

The results showed that using different primers (P2-M17, P2-M16 and P2-M21) polymorphism in the length of DNA molecular was identified. This phenomenon revealed that there is existence of virus on banana plant. The Cavendish group AAA was tested and a visible result was observed.

**Difficulties**

During past years, banana production has not been developed due to an extensive cultivation of (?) banana production, use of undeveloped
techniques and low quality of plant material together with infection by pathogens. A poorly developed commercial system leads to it that banana is only locally consumed. Moreover banana fruits are used fresh 100% in banana season so post harvest and processing industry is poorly developed. Investment into research on banana is not considered as a particular program, therefore results of research have not impacted really on mass production.

**Research plans and cooperation in the future**

**Plans for the future**

- Strengthen research activities, apply achievement of molecular technique and genetic transformation to create and select new varieties with good quality and high resistance capacity to biotic characters.

- Provide for different agro-ecological regions with improved suitable and valuable varieties and organize to test them through the Vietnamese banana network.

- Construct intensive farming model of banana production with suitable cultivation technique and proper management

**Cooperation**

Strengthen cooperation on different aspects:

- Nematology studies (identification, classification and evaluation in the greenhouse and in the field)

- Molecular technique and genetic transformation

- Post harvest and processing technology: ripening, conserving

- Looking for establishment of market consumption

**References**


Banana R&D in the Pacific

Tom Osborn*

Banana industry status

Bananas rank as one of the most widely grown and consumed crops in the Pacific. They are produced in all of the ecologies of the Pacific Island countries, from the large volcanic islands to the small coral atoll countries. Bananas are significant for the nutrition of Pacific Islanders as green cooking bananas, semi-ripe cooking bananas, ripe cooking bananas, dessert bananas and mixed with other foods. Bananas are grown for household consumption and on small commercial farms for the local markets. There is also deep cultural significance associated with bananas for traditional rituals in many countries. Bananas are used for medicine, fiber, leaves for cooking and livestock feed.

There is a wide diversity of banana lines in the Pacific. Papua New Guinea, Solomon Islands and Vanuatu have the greatest diversity. The regional diversity includes AA diploids, the very popular AAA Cavendish types and the AAB cooking plantains. The Fe’i group of bananas - in the *Australimusa* section rather than the *Eumusa* section of the genus - is unique to the Pacific. The Fe’i bananas have erect bunches and purple sap. For example the Karat variety of Fe’i bananas of Pohnpei in the Federated States of Micronesia has short plump fruits with orange flesh that require cooking. They are very high in vitamin A and have been used as a weaning food. Unfortunately, the Fe’i bananas are rapidly disappearing in the Pacific.

FAO production data indicated production of 53 402 tonnes in 2001 on 9155 hectares, suggesting an average production of 5 tonnes per hectare for the Pacific excluding Papua New Guinea (Annex 1). Additional information from the agriculture census of Samoa, and reports from other countries, suggests that the FAO figures under-estimate banana production in the Pacific.

- Estimates from New Caledonia indicate yields of 20-40 tonnes per hectare for dessert bananas and 9-12 tonnes/hectare for cooking bananas.
- Agriculture census data from Samoa indicate 10 000 equivalent

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*Agriculture Adviser, SPC, Suva, Fiji.*
acres of banana production and consumption of 3 bunches per family per week (mostly as cooked green bananas).

Despite their nutritional importance, bananas are not a priority crop for national agricultural research and extension programmes in most Pacific Island countries because it is currently not an important cash crop. As a result, funding for banana research and development is limited.

**Production constraints**

There are a variety of constraints to banana production in the Pacific Island countries. Normally, banana is a part of the traditional multicropping system of the Pacific Islands that can include some or all of the following crops: coconuts, taro, sweet potatoes, kava, yams, cassava, cacao, breadfruit and many other crops. There are also small monocrop plantations of bananas in some countries.

**Pests and diseases**

- *Mycosphaerella fijiensis*, black leaf streak (BLS), is probably the most destructive pathogen of bananas in the Pacific. Farmers seldom spray for this disease and therefore, there is a substantial reduction in yield.

- Banana Bunchy Top Virus (BBTV) is widespread, creating problems for producers where it is spread by the banana aphid, *Pentalonia nigronervosa*. Recently, New Caledonia conducted a campaign to eradicate BBTV and so far 200 000 plants have been destroyed. However, it is very difficult to succeed in such an endeavour when bananas are so widely grown in traditional systems.

- Nematodes are destructive in many locations.

- Banana weevils, *Cosmopolites sordidus*, cause damage in some countries.

- Banana scab moth, *Nacoleia octasema*, is widespread and results in low quality bananas and reduced yields in some cases.

**Environmental stresses**

- Cyclones and high wind are damaging to bananas, particularly the taller varieties.

- Drought, particularly on atolls, greatly reduces banana production.

- Salt spray on small islands damages bananas.
• Poor soil fertility reduces yield, fruit size and quality. Fertilizer is seldom used on banana, however the tradition is to use animal manure and organic matter.

Markets

Bananas was a major export earner for the Pacific Islands until the 1970s with exports going to New Zealand and other developed country markets. However, the large transnational banana producers then captured these markets based on price and quality, so the Pacific countries’ profitable export markets quickly disappeared. There are still a few small banana exporters in the region, based on niche exports such as organic banana. The major constraint to banana production is thus a lack of an export market to absorb higher levels of production. The result is that farmers are limited to the small local market or producing from home consumption. They lack the incentive to invest in increased production and improving the quality of bananas. This also means that NARS do not target bananas as a priority crop for research and extension.

Current banana research and development

SPC Regional Germplasm Centre

The SPC Regional Germplasm Centre distributes accessions of bananas, taro, yams, sweet potatoes and other vegetatively propagated crops to the 22 SPC member countries and territories. INIBAP has provided FHIA lines and modest funding for the multiplication and distribution of new banana lines in the region. FHIA-01, -02, -03, -17, -18, -23 and -25 have been distributed to American Samoa, Cook Islands, Federated States of Micronesia (FSM), Marshall Islands, New Caledonia, Palau, Samoa, Solomon Islands, Tonga, and Wallis and Futuna. Distribution of thousands of accessions of the FHIA lines is continuing. Reports indicate interest in the material, but in most cases the new lines have not reached farmers’ fields yet.

• Recent results from New Caledonia indicate FHIA-17, -18 and -23 had excellent BLS resistance but grew very slowly during and after the cool dry season. Earlier results of organoleptic testing indicate that FHIA-01 is acceptable as a dessert banana and FHIA-02 is acceptable as a cooking banana. These lines are being distributed to farmers for testing.

• In the FSM, the FHIA trials conducted by the community college indicate the resistance to BLS is excellent but organoleptic tests have not been conducted yet.
American Samoa reported that FHIA-25 produces well and is resistant to BLS, but Samoans prefer a cooking banana with a harder texture. Suckers are being distributed to farmers for further testing.

FHIA-01 has been distributed in Samoa for many years. An INIBAP-funded survey in Samoa through the University of the South Pacific indicates acceptance of FHIA-01.

In Wallis and Futuna the FHIA lines are being distributed to farmers.

There have been problems with confusion over the identification of the 7 FHIA lines. What is needed is a guide to the identification and characteristics of the lines. We hope that this will be available soon.

New Caledonia

Since 1990, the Pocquereux Fruit Research Station of the Institute of New Caledonian Agriculture (with links to CIRAD) has had a banana research programme to control BLS through chemical methods, selection of BLS tolerant banana cultivars and epidemiological studies to better understand the interaction between the pathogen, the plant and the climate. These efforts are linked with extension efforts with both subsistence and commercial banana producers. Pocquereux also participates in the Musa Germplasm Information System (MGIS). The station is one of the BLS evaluation sites for the Banana Improvement Project (BIP), which evaluates 80 different cultivars with the aim of selecting diploids as parents for breeding programmes. This is our leading center of banana research in the region.

ACIAR/QDPI Banana Improvement Project

This project conducted important banana research in the Pacific during the late 1980s and early 1990s, with collaborating Ministries of Agriculture in the Cook Islands, Samoa and Tonga. Trials were conducted to screen improved banana lines for pest and disease resistance as well as to better understand these pests. Training and technical assistance were also an important component of this project. It is important to note that QDPI and other Australian banana researchers are an important source of technical assistance for the Pacific Islands on banana-related problems.
**Future Directions for Bananas in the Pacific with INIBAP**

**Multiplication and distribution of improved banana lines**

The SPC Regional Germplasm Centre will continue to multiply and distribute improved banana lines to the Pacific countries. At the present, this includes mostly the FHIA lines, but we hope that other new lines with characteristics that are appropriate for the Pacific will be coming from INIBAP.

- We hope that there will be a publication of a FHIA identification guide through INIBAP

**Diversity analysis for banana**

The action plan developed in September 2001 for the newly established Pacific Agricultural Plant Genetic Resources Network (PAPGREN) included mention of the need for diversity analysis of bananas. This would be carried out in close collaboration with IPGRI/INIBAP, using a variety of tools and information sources. The newer techniques will complement the more traditional indicators of diversity, such as morpho-agronomic and ethno-botanical studies. As a result of this study, several activities could be developed.

**Targeted collecting, e.g.**

- AAB cooking bananas with resistance to BLS
- Identification of resistance to BBTV
- Dwarf plantains AAB for breeding
- Fe‘i bananas

**Nutritional studies for the Fe‘i bananas**

Importation research has been conducted in the FSM led by the nutritionist Lois Englberger (Annex 1 and references). Additional work needs to be undertaken to understand the nutritional analysis in relation to the diversity. In this way, this unique group can be conserved and utilized to improve the nutritional status in areas with vitamin A deficiency and other related nutritional problems.

**Development of a regional collection for Pacific bananas**

The result of the diversity studies and targeted collection could result in a valuable collection of bananas for multiplication and distribution to the Pacific Island countries and territories. This would be an
important output for PAPGREN and the Regional Germplasm Centre of SPC.

On farm conservation

There was useful input from INIBAP to the recent workshop on on-farm conservation in the Pacific, highlighting PNG, Fe‘i bananas and Pacific plantains in New Caledonia as priorities for action. As PAPGREN develops plans for in situ conservation (both on-farm and in protected areas) in the region, bananas will no doubt feature prominently.

References


Figure 1. Banana production in the Pacific (not including PNG).

Table 1. Area of production and yield of banana in the South Pacific.

<table>
<thead>
<tr>
<th>Area</th>
<th>Production</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNG</td>
<td>50 000</td>
<td>710 000</td>
</tr>
<tr>
<td>Rest of Region</td>
<td>9 155</td>
<td>53 402</td>
</tr>
<tr>
<td>Total</td>
<td>59 155</td>
<td>763 402</td>
</tr>
</tbody>
</table>

Cook Islands  
Fiji Islands  
French Polynesia  
Guam  
Kiribati  
FSM  
New Caledonia  
Nue  
Samoa  
Solomon Islands  
Tokelau  
Tonga  
Tuvalu  
Vanuatu  
Wallis and Futuna Is
Annex 1

Fe’i banana research in the Federated States of Micronesia

Health research relating to banana has been conducted by the nutritionist, Lois Englberger, in Kosrae and Pohnpei, two of the four states of the Federated States of Micronesia (FSM). The overall aim of her research related to identification of foods which might contribute to vitamin A status, as vitamin A deficiency has been identified as a serious health problem in the country, both among children and women, affecting not only eye health and vision but increased morbidity and mortality. Her work on banana has included:

- An analysis for provitamin A and other carotenoids and selected minerals;
- An ethnographic study providing insight into the factors affecting production, acquisition, consumption and acceptability of the different cultivars;
- A dietary study that showed banana fits into the present daily diet.

Provitamin A carotenoids, most importantly beta-carotene, contribute to vitamin A status and protection against vitamin A deficiency. Epidemiological evidence indicates that consumption of carotenoids (including those which have no vitamin A activity) decreases risk to certain chronic diseases, such as cancer, heart disease and diabetes, which have also become serious health problems in FSM. Yellow and orange coloration of the edible flesh was used for selecting those cultivars for analysis which might have the most potential for health benefits, based on the fact that carotenoids often may be identified by those color traits. Some common cultivars without yellow or orange coloration were analyzed for purposes of comparison. Increased coloration was found to closely match with increased carotenoid content, with five distinct colors identified in the cultivars, white, creamy, yellow, yellow-orange and orange.

In all, 17 banana cultivars from Kosrae and Pohnpei were analyzed and characterised. There was a great range of carotenoid content, from 30 to 6360 µg/100 g edible portion. The Karat banana cultivar was found to contain over 25 times the beta-carotene content of the common Cavendish, and the Uht En Yap cultivar was found to contain 250 times the beta-carotene content of the common Cavendish. Thirteen Micronesian cultivars were identified which would provide the total or up to half of the estimated daily requirements for vitamin A, within normal eating patterns.

It was concluded that certain cultivars of banana have particular potential in FSM for providing important health benefits and decreasing risk to vitamin A deficiency and chronic diseases. On that basis, it was concluded that these cultivars should be promoted for family consumption and possible commercialization. Lack of planting material is a major limitation at present. A study of Chuuk and Yap cultivars has not yet been carried out. It is suggested that nutritional projects, in conjunction with agricultural agencies, would have great benefit for both the health and agriculture sectors in FSM. It is also suggested that certain banana cultivars elsewhere may be identified for promotion and increased health and enjoyment.
Somaclonal variation approach to breeding Cavendish banana for resistance to fusarium wilt race 4

Shin-Chuan Hwang*

Abstract
Fusarium wilt of banana, caused by *Fusarium oxysporum* f. sp. *cubense* (*Foc*) race 4, is the major constraint for cultivation of banana in Taiwan. For obtaining a resistant variety to replace the susceptible Cavendish, Taiwan Banana Research Institute (TBRI) initiated an innovative breeding program based on somaclonal variation approach. This breeding program which began in 1984, already produced a total of 13 resistant/tolerant clones; all derived from the wilt-susceptible variety Giant Cavendish. To solve the fusarium wilt problem, three of them were released as the new varieties, Tai-Chiao No.1 in 1992, Tai-Chiao No.3 in 2001 and Formosana in 2002, for commercial production. The former two varieties are mediocre in resistance to fusarium wilt and in productivity, and moderate success has been obtained. Formosana not only showed a high level of resistance to fusarium wilt but also produced a bunch about 40% heavier than that of its progenitor Giant Cavendish, a breakthrough in banana breeding. This new variety was released for commercial planting beginning January 2002 to replace both Tai-Chiao No.1 and Tai-Chiao No.3. With its superb agronomic and horticultural characteristics, it is believed that Formosana will soon become the major banana variety grown in Taiwan. The novel breeding strategy based on somaclonal variation has proved to be a useful method for the improvement of banana.

Introduction
In Asia, the oldest international banana trade exists in Taiwan where banana production for exporting to the neighbouring Japanese market began in the early 1900s. The banana industry, involving small producers mostly, expanded rapidly and reached the peak production on over 50 000 hectares in the mid-1960s, ranking Taiwan the second largest banana-exporting country in the world. Under the subtropical climate, bananas produced in Taiwan have top eating quality, and they are highly esteemed in the Japanese market.

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Over the last 20 years, production of Cavendish banana in Taiwan, however, has been seriously jeopardized by the intractable fusarium wilt (Hwang 1985; Su et al. 1977). The fungus attacking Cavendish, previously considered highly resistant to this disease, belongs to the type of race 4 of Foc (Su et al. 1977). The disease, found in 1967, has spread rapidly to epidemic proportions within few years and caused considerable losses to the banana growers. At present, about 4000 of the total 6000 hectares of banana growing in the central and southern part of Taiwan is affected. Attempts in controlling the disease using soil sanitation, soil fumigation and soil amendment, etc. were unsuccessful (Hwang 1985; Su et al. 1986). A commercially acceptable resistant variety is needed, urgently.

Banana breeding based on the traditional crossing (pollinating) approach is extremely difficult, for Cavendish especially, because of the female seed sterility inherent in Cavendish varieties. Over seventy years of crossing a short Gros Michel with a resistant diploid to obtain a resistant tetraploid competitive with the Cavendish cultivars has been unsuccessful (Stover and Buddenhagen 1986). For this reason, for obtaining a fusarium wilt resistant Cavendish, an innovative breeding approach based on somaclonal variation was taken by the TBRI in 1984 (Hwang and Ko 1988; 1991). This paper gives an account of the progress this breeding program has made highlighting the recent development of a superb high-yielding, fusarium-resistant variety, Formosana, a breakthrough in banana breeding.

**In vitro propagation and somaclonal variation**

Although *in vitro* propagation of vegetatively propagated crops such as banana has shown the potential for producing substantial genetic variability, known as somaclonal variation (Snowcroft and Larkin 1982), it is generally believed that the probability of success in obtaining an improved Cavendish clone that also corrects its susceptibility to fusarium wilt race 4 based on somaclonal variation would be extremely low, if not impossible. The key to the success is to produce a large number of seedlings *in vitro* for screening.

The initiative of the development of tissue culture program at TBRI came from the fusarium wilt. As a systemic disease, it spreads readily through the movement of infested suckers, the conventional planting material used by farmers (Hwang 1985; Su et al. 1986). The adoption of disease-free plantlets by farmers has proved useful to check the spread of the disease (Hwang et al. 1984; Su et al. 1986). Field surveys revealed that these plants showed up to 3% somaclonal variation
(Hwang 1986). A wide range of mutated traits is found including stature, leaf shape, plant color, and pseudostem and fruit characteristics, etc. Some are detectable when plants are young and others after flowering. Most somaclonal variants were genetically stable, thus offering an option for the improvement of banana cultivars.

Because using *in vitro* plantlets also has the advantages of having a higher survival rate than suckers, lower cost in disease and pest control and a shorter harvesting period, etc., more and more banana growers have begun using plantlets to establish their fields. TBRI has mass-produced more than 2 millions of disease-free plantlets of a Cavendish variety Giant Cavendish each year for use by farmers and for research including breeding (Hwang and Su 1998).

**Resistant clones identified in screening program**

A mass-screening program for detecting resistance to Foc race 4 that began in 1984, was set up by planting *in vitro*-produced plantlets in a nursery soil heavily infested with diseased tissue (Hwang and Ko 1988; 1991). The diseased tissue was plowed and thoroughly mixed with soil in order for the pathogen to distribute uniformly, maintaining an inoculum dose ranging from 300 to 1000 propagules/g soil throughout the testing. Two-month-old plantlets of the wilt-susceptible varieties propagated by the method (Hwang *et al.* 1984) were used for screening by planting them at high density (20 000 plants/ha) in the nursery. After 3-4 months, depending on seasonal temperature, the surviving plants were dug up and the rhizomes examined for infection. Those free of infection were again multiplied *in vitro* for additional tests to confirm resistance.

From 1984 to 1986, about 30 000 tissue-cultured plants of Giant Cavendish were screened and ten resistant clones selected, following final evaluation (Hwang and Ko 1988; 1991; 1992). From 1992 to 1995, two resistant clones were found among 11 180 tissue-cultured plants of Tai-Chiao No.2, a semi-dwarf Cavendish cultivar (Hwang and Tang 2000). The efficiency of selection was about two to three resistant clones for every 10 000 plants screened. Among the ten selected clones derived from Giant Cavendish, five were highly resistant with a disease incidence of less than 10%, while the other five were moderately resistant, with an infection rate of 10-30%, compared to over 70% in Giant Cavendish. The horticultural characteristics of these resistant clones are presented in Table 1.
In addition to the normal screening procedure, work on selection was also conducted on the ordinary commercial farms, in collaboration with farmers. By 1990, the tissue-cultured plants had already grown widely on more than half of the banana farms, and many of these farms were invaded by the fusarium wilt, seriously. On these farms, selection was targeted at those apparent healthy plants occasionally found in disease hot spot, with special attention to those showing morphologically different from the normal Giant Cavendish plant but bearing normal bunches. Suckers of these putative resistant plants were collected and further multiplied in vitro for testing against Foc race 4. Clones GCTCV-216, GCTCV-217 and GCTCV-218 were selected this way (Hwang and Tang 2000).

Table 1. Horticultural characteristics of Foc race 4-resistant clones derived from Giant Cavendish by somaclonal variation.

<table>
<thead>
<tr>
<th>Clone</th>
<th>Resistance</th>
<th>Horticultural Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCTCV-40</td>
<td>High</td>
<td>Tall and slender pseudostem; weak petiole with narrow and drooping leaves; small bunch</td>
</tr>
<tr>
<td>GCTCV-44</td>
<td>High</td>
<td>Short and slender pseudostem; weak petiole and drooping leaves; bunch normal but weak pedicel</td>
</tr>
<tr>
<td>GCTCV-46</td>
<td>Moderate</td>
<td>Black spots on pseudostem and leaf sheath; upright leaves; small bunch with short fingers</td>
</tr>
<tr>
<td>GCTCV-53</td>
<td>Moderate</td>
<td>Dark green pseudostem; drooping leaves; elongate male bud; small bunch with short fingers</td>
</tr>
<tr>
<td>GCTCV-62</td>
<td>Moderate</td>
<td>Pale green pseudostem; fewer suckering; small bunch and fingers.</td>
</tr>
<tr>
<td>GCTCV-104</td>
<td>High</td>
<td>Pale green pseudostem; fewer fingers; long growing cycle</td>
</tr>
<tr>
<td>GCTCV-105</td>
<td>High</td>
<td>Shorter and slender pseudostem; compact bunch with more number of short fingers</td>
</tr>
<tr>
<td>GCTCV-119</td>
<td>High</td>
<td>Very tall; wavy leaves; short fruit stalk; long growing cycle; fewer hands but large fingers; sweeter fruit</td>
</tr>
<tr>
<td>GCTCV-201</td>
<td>Moderate</td>
<td>Robust pseudostem; short fruit stalk; malformed hands</td>
</tr>
<tr>
<td>GCTCV-215</td>
<td>Moderate</td>
<td>Tall and slender pseudostem; leaf tip curl and splitting; fewer suckering; normal bunch but slender fingers; long growing cycle</td>
</tr>
<tr>
<td>GCTCV-216</td>
<td>Moderate</td>
<td>Very tall; very large and heavy bunch; long growing cycle</td>
</tr>
<tr>
<td>GCTCV-217</td>
<td>High</td>
<td>Erect leaves; compact, but heavy bunch; less curved fingers</td>
</tr>
<tr>
<td>GCTCV-218</td>
<td>High</td>
<td>Robust pseudostem; wider and thicker leaves; very heavy bunch with more number of hands; less curved fingers; long growing cycle</td>
</tr>
</tbody>
</table>

GCTCV- Giant Cavendish tissue-cultured variant.
High - disease incidence less than 10%; Moderate - disease incidence of 10-30%.
Improvement of resistant clones

With exception of the latest selected clone GCTCV-218 which is horticulturally superior to its progenitor Giant Cavendish, all the rest of resistant clones are inferior either in agronomic traits or in yield (Hwang and Ko 1988; 1989). As indicated in Table 1, many resistant clones possess undesirable agronomic characters such as excessive height, weak petiole with drooping leaves, and produce under-sized bunch, while others like GCTCV-216 and GCTCV-217 produce heavy bunches but having too large hands of the former and too short fingers of the latter, rendering them unacceptable to the market. Selection of improved variants from these inferior resistant clones was attempted, again based on somaclonal variation approach.

When large numbers of tissue-cultured plantlets of resistant clones were planted in the field, a few plants with improved agronomic characters were found in each clone (Hwang and Ko 1989). These improved types had thicker pseudostems, grew faster, and produced bigger bunches than their respective resistant progenitors. The clone GCTCV-119 for instance, the bunch weight of the original resistant parent was 17.2 kg, only, while that of the improved variant was increased up to 26.5 kg. The growing cycle of the improved variant was also shortened from 15 months of its progenitor to 13 months only. The frequency of improved variants found in these resistant clones varied from 0.2 to 10.1% (Hwang and Ko 1989). Of considerable interest is that the gene(s) conferring resistance to Foc race 4 in most of the resistant clones appears to be transmissible to their respective improved variants. Among these four improved variants tested, GCTCV-44-1, GCTCV-53-1 and GCTCV-119-1 remained to be resistant to Foc race 4, and GCTCV-40-1 only had lost wilt resistance (Hwang and Ko 1989) as shown in Table 2.

Table 2. Fusarium wilt on improved variants compared to their resistant parents.
Further work on improvement of these resistant clones each year based on somaclonal variation has led to the continued discovery of many new, useful, resistant improved variants. Two of them, GCTCV-215-1 and TC1-229, were released for commercial production in 1992 and 2001, respectively (Hwang et al. 1994; Hwang and Tang 2000).

**Release of resistant clones for commercial planting**

About 70% of Cavendish banana production in Taiwan is consumed locally and 30% is exported to the neighbouring Japanese market. Bananas entering the Japanese market, the most competitive market in the world, receive the best price and must match the highest quality standards. Based on the results of field performance and fruit quality evaluation of these resistant clones developed by the breeding program, GCTCV-215-1, TC1-229 and GCTCV-218 were acceptable to both farmers and market and were released officially for commercial production.

GCTCV-215-1, a moderately resistant clone was released in 1992 as the new variety Tai-Chiao No.1 for commercial production on over 1500 ha (Hwang et al. 1994). This is the first release anywhere of a mutated Cavendish variety. It was selected in 1988 and is the secondary variant of GCTCV-215. It is slightly taller than Giant Cavendish and has a more slender pseudostem and longer growing cycle. Although the bunch weight of this new variety is about 10% lighter than that of Giant Cavendish, it is reputed to have more uniform bunch shape and more even ripening, giving better fruit quality. Surveys in infested fields planted with this new variety showed that the percentage of wilt incidence averaged 6.5% in 1994 and 5.1% in 1995, while the incidences for Giant Cavendish were 69.0 and 42.6% (Hwang et al. 1994; Hwang and Tang 2000). The release of Tai-Chiao No.1 has reduced considerably the yield loss to fusarium wilt and enabled growers to resume banana production on many abandoned infested farms.

TC1-229, a semi-dwarf variant of Tai-Chiao No.1, was selected from a farmer’s field in 1992 (Hwang and Tang 2000). It is about 50-70 cm shorter than its progenitor Tai-Chiao No.1. Other traits such as growth cycle, bunch weight and level of resistance to Foc race 4, were not significantly different from those of Tai-Chiao No.1. Since wind damage is one of the major constraints for cultivation of banana in Taiwan, planting the shorter variety would reduce yield losses and facilitate farm management. For this reason, the clone was released in 2001 as the new variety Tai-Chiao No.3 for commercial production.
GCTCV-218. The clone was discovered by a farmer on his farm planted with tissue-cultured plantlets of Giant Cavendish provided by TBRI. Resistance to Foc race 4 of this new clone, designated GCTCV-218, was confirmed following a series of tests conducted at TBRI experimental farm followed by semi-commercial trials on grower’s farms.

Results of these studies revealed that both disease resistance and higher-yielding characteristics of GCTCV-218 were fairly stable across a wide range of environment regimes. Fusarium wilt incidence on GCTCV-218 averaged 4.1%, ranging from 1.6 to 12.2%, which is significantly lower than 9.8% of the wilt-tolerant variety Tai-Chiao No.1 and 29.6% of the wilt-susceptible variety Giant Cavendish. The weight of bunches harvested from GCTCV-218 averaged 30.6 kg, which is 10.1 kg on average heavier than that of Giant Cavendish.

The new clone, about 2.8 m tall, also beats the Giant Cavendish in other agronomic traits such as having more robust pseudostem, stronger petioles, thicker leaves, better hand formation, and being more uniform in the size of hands. The fruit was of high quality and received favorable response from both the Japanese and local market. A comparison of salient features between GCTCV-218 and its parent variety Giant Cavendish is shown in Table 3.

GCTCV-218, officially named Formosana, was released for commercial planting on 1500 ha in January 2002 to replace both Tai-Chiao No.1 and Tai-Chiao No.3 for the first year. It is estimated that planting GCTCV-218 would result in an increased yield from 32.4 to 51.6 t/ha on fusarium-infested farms, and from 38.4 to 54.5 t/ha on clean farms, accounting for 59% and 42% of yield increase, respectively.

Table 3. Comparison of salient features between Formosana and Giant Cavendish on the first plant crop.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Plant height (cm)</th>
<th>Pseudostem girth (cm)</th>
<th>Leaf ratio</th>
<th>No. of hand/bunch</th>
<th>No. of finger/bunch</th>
<th>Bunch weight (kg)</th>
<th>Crop cycle (month)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GC</td>
<td>274</td>
<td>73</td>
<td>2.50</td>
<td>8.5</td>
<td>147</td>
<td>21.3</td>
<td>12</td>
</tr>
<tr>
<td>FM</td>
<td>281</td>
<td>82</td>
<td>2.33</td>
<td>11.5</td>
<td>191</td>
<td>30.2</td>
<td>13</td>
</tr>
</tbody>
</table>

GC: Giant Cavendish; FM: Formosana; Data are means of two crop cycles.

Conclusion

For decades, banana production in Taiwan has been greatly challenged by the intractable fusarium wilt problem. For the control, the susceptible variety Giant Cavendish must be replaced by the resistant variety. For obtaining a resistant Cavendish whose breeding based on
crossing has been seriously handicapped by the female seed sterility, an appropriate method for breeding must be developed. Because in vitro propagation of banana has shown the potential for producing substantial genetic variability, a novel approach based on somaclonal variation was taken by TBRI in 1984 (Hwang and Ko 1984). Much interest, support and effort have been devoted in this direction over the past 16 years leading to the continued discovery of many interesting, useful resistant clones and to the release of three commercially acceptable resistant varieties, Tai-Chiao No.1, Tai-Chiao No.3 and Formosana for commercial production in Taiwan. The most ideal variety Formosana is now planted in about 1500 ha of infested farms, saving the banana industry from destruction by fusarium wilt.

The most significant achievement made by this breeding program is the successful development of the superb variety, Formosana. The plant brings together many useful traits including fusarium wilt resistance, high-yielding, improved agronomic characters and improved fruit quality, a breakthrough in banana breeding. This is the most productive Cavendish considered by TBRI. Commercialization of Formosana would have great impact on Taiwan banana industry. First, it would reduce the loss of production to fusarium wilt from the present 15% level to less than 5% every year. Second, the yield per hectare would be increased by over 50%, hence greatly reducing the production cost, the key constraint for banana production in Taiwan. Third, for decades, Taiwan banana has been suffering a seasonal uneven ripening problem that greatly reduces its competitiveness in the Japanese market. Planting Formosana to replace Giant Cavendish will solve this problem for bananas produced by Formosana ripen evenly. Fourth, it is believed that planting the most productive Cavendish variety Formosana has great potential for Taiwan bananas to enter the new export markets because of its lower production cost and better fruit quality, thus more competitive on international market.

In comparison with the traditional banana breeding based on crossing (pollinating) which has not produced any improved Cavendish variety for commercial use over the past 70 years, the somaclonal variation breeding has proved to be an efficient, useful approach for the improvement of Cavendish cultivars. The innovative approach has the following features that make the selection so efficient and thus the goal of breeding attainable.

1. A wide range of genetic variability found among in vitro mass-produced plants offers a higher probability of success in selecting desirable mutated traits. As shown in this study, the chance of
success of selection for resistance to fusarium wilt was about two to three clones for every 10 000 plants screened (Hwang and Ko 1988; Hwang and Tang 2000).

2. Most mutated traits occurring in somaclonal variation including resistance to fusarium wilt are genetically stable across a wide environment range, as demonstrated by the field performance of the oldest released variety Tai-Chiao No.1. Since its selection in 1988 and commercialization in 1992, about five million tissue-cultured plants of Tai-Chiao No.1 have been propagated and distributed to farmers. The agronomic traits and level of resistance have shown to be consistent from crop to crop over the years (Hwang and Tang 2000).

3. Although most resistant clones originally obtained from the breeding program have major deficiencies, somaclonal variation approach offers the chance to select the improved types from their in vitro-derived progenies (Hwang and Ko 1988; Hwang and Tang 2000). Thus, breeding of banana this way can be like for other crops, making it much less a ‘dead-end’ game. The secondary semi-dwarf improved variant TC1-229 and tertiary semi-dwarf improved variant TC1-600 obtained from the taller progenitor Tai-Chiao No.1 (Hwang and Tang 2000) are cases in point.

4. The tissue culture program that began in 1983, has produced more than two million seedlings each year for use by farmers. Work on selection, through linkage to this tissue culture program, can be conducted extensively on commercial farms in collaboration with farmers, thus increasing the chance of success of selection and making the selection cheaper as well. The best resistant variety Formosana was discovered this way.

Banana breeding by somaclonal variation approach is now widely used in many other breeding programs in various countries. In addition to Cavendish, it is believed that this method would be applicable to other types of banana and for inducing resistance to other major diseases including black sigatoka, nematodes, and even to viral diseases as well. The genetics of fusarium wilt resistance of banana is not known. With the rapidly advancing biotechnology in the area of DNA mapping, these resistant/tolerant somaclones will be useful for identifying gene(s) that confer resistance by comparing the expressed DNA of a resistant somaclone with that of its susceptible progenitor. It would be also interesting to determine if the enhanced resistance in these somaclones is due to mutations to different or similar genes.
References


INIBAP programs and technical presentations
The Banana Asia Pacific Network (BAPNET): A platform for Musa R&D collaboration

Agustin B. Molina*

Bananas and plantains are fruits most extensively grown in Asia. The fruits are non-seasonal and therefore consumed the whole year round. As the premier fruit of the region, bananas and plantains contribute significantly to the diet and nutrition of the people, particularly the poor. This important fruit commodity, which is grown primarily for domestic consumption, is an important source of income to numerous small farmers and entrepreneurs.

In November 1984, a group of countries and organizations established the International Network for the Improvement of Banana and Plantain (INIBAP) with headquarters in Montpellier, France. INIBAP’s mandate includes coordination of research efforts, dissemination of research information and generation of funds to support priority research and development activities on bananas and plantains. Recognizing the enormous complexity involved in world banana agriculture and to ensure relevance and flexibility in its program thrusts, INIBAP decided to set up regional networks in West Africa, East Africa, Latin America and the Caribbean and finally Asia and the Pacific in 1991.

Asia is the recognized Center of Origin of the genus Musa and possesses the greatest wealth of banana germplasm in the world. It is also the source of practically all commercial cultivars of dessert bananas and holds an enormous collection of hardy and high-yielding cooking bananas with great potential for the other regions of the world. The Asia-Pacific Network (ASPNET) in 1991 started with Australia, China, India, Indonesia, Malaysia, Philippines, Thailand, and the Taiwan Banana Research Institute (TBRI) as its initial members and later expanded to also include Bangladesh, Sri Lanka, Vietnam, Pakistan and the Secretariat of the Pacific Community (SPC).

The relaunching of the regional network

While INIBAP is pleased with the progress made by the network, there was a need to review the modus operandi of the network under the framework of the Memorandum of Agreement (MOA) of collaboration signed between IPGRI International Plant Genetic Resources Institute

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(IPGRI) and the Asia Pacific Association of Agricultural Research Institutions (APAARI) and to revisit its aims and objectives, with the aim of re-launching the network as a truly NARS-based initiative enhanced by INIBAP networking activities. This meeting was held in Sri Lanka in October 2001 with the presence of representatives of Australia, Bangladesh, China, India, Indonesia, Malaysia, the Philippines, Thailand, SPC and TBRI. A new member, Cambodia, was invited to the meeting. Highlights of the meeting were as follows: formulation of the logical framework which would help in the development of a constitution, renaming of the network to Banana Asia Pacific Network (BAPNET) and invitation for Papua New Guinea as an additional member of the network separate from SPC.

Regional approaches to identify agricultural research and development priorities are now given much attention. There is a growing concern as to how regional priorities can be matched with national and international priorities, taking care of the R&D needs of the national systems. It is expected that the re-launching of BAPNET would result to stronger partnership among NARS to pursue agreed research agenda for greater mutual benefit. INIBAP-Asia Pacific on the other hand, would catalyze activities of BAPNET like coordination, publication of regional materials, information dissemination, fund sourcing as well as link BAPNET to INIBAP’s global programmes such as the International *Musa* Testing Program (IMTP) Phase III, germplasm management (i.e. *Musa* Germplasm Information System [MGIS]), collection, conservation and characterization) and the Global Programme for *Musa* Improvement (PROMUSA).

**Significance of BAPNET**

The former structure of collaboration in the region (ASPNET) was in place but it was aimed at establishing priorities for INIBAP, rather than for the activities of existing NARS. With the BAPNET operating within the APAARI framework, collaboration is expected to be with a more coherent research strategy for the region, based on the needs and priorities of the participating countries. Most countries in the region have an established national banana network and corresponding research programmes. Therefore, regional priorities can easily be identified and established resulting to a coordinated approach and create synergy to banana research in the region. Continued collaboration in banana research in the region is essential to avoid duplication thereby enhancing efficiency of research. This is essential as there is a growing interest of the donor community in crops not traditionally researched and those with important roles in poverty
alleviation. A regional capacity building programme for human resource development can also be developed and organized.

BAPNET promotes cooperation in exchange of germplasm, technologies and information. Furthermore, problems on unfavorable policies related to world trade, fluctuating economic conditions in the region resulting to unprofitable banana cultivation venture and movements of pest and diseases can be discussed.

**Role of INIBAP-AP in enhancing the network**

**Secretariat**

BAPNET has appointed the INIBAP-AP as its Secretariat with the Regional Coordinator (RC) as Executive Secretary. The major role of the Secretariat is to provide the overall organizational management of BAPNET. Among its specific activities are: (1) facilitate the networks’ activities in the areas of training, germplasm conservation, enhancement, evaluation, utilization, information systems and publications; (2) facilitate the development and implementation of the BAPNET strategic plan; (3) facilitate communication/information exchange between network members; (4) lead efforts to source funding for BAPNET; (5) facilitate the provision of technical assistance; (6) represent the needs of the region to INIBAP; and (7) inform the Steering Committee of activities in Global Programmes relevant to the region.

**Annual Steering Committee meeting**

In this regard, INIBAP-AP sponsors the annual meeting of the Steering Committee with one of the members as host. INIBAP provides the forum where regional policies and strategic plans are discussed. Priority areas for research and development as well as training opportunities are identified. The members have the opportunity to present their national programs and to check which can run in tandem with the regional programs of BAPNET and furthermore with the global programs of INIBAP.

Regional programs can also be developed, packaged, and submitted to possible donors. The RC can lead efforts for fund sourcing for these regional programs. Moreover, he can represent the needs of the region to INIBAP.

**Link BAPNET to global programs**

BAPNET provides a link to the global programs of INIBAP such as the IMTP III, MGIS and Collection, Conservation and Characterization.
The IMTP is an INIBAP coordinated global testing of elite materials, clones, and cultivars developed from *Musa* breeding programmes in various countries of the world. These are tested for its resistance to fusarium, sigatoka and nematodes, yield and adaptability to local conditions. The MGIS is a database wherein various curators of banana germplasm collections contribute taxonomic descriptions and agronomic evaluations of their collections. The Asia Pacific region is a major contributor to this database. MGIS provides an access to a comprehensive data on the many germplasm collections worldwide. Collecting missions in Vietnam, China and the Philippines have been accomplished. Collecting missions are still ongoing in Indonesia and India. Most of the members of the network are participating in these global programs.

**Link BAPNET to PROMUSA**

The PROMUSA was developed as a means to bring together all the major efforts in the area of *Musa* improvement. The global programme builds on existing achievements and is based on ongoing research initiatives. PROMUSA is therefore a mechanism to further maximize the outputs and accelerate the impact of the overall *Musa* improvement effort. It provides a platform of collaboration among *Musa* researchers worldwide in a flexible mechanism that can promote and result to many kinds of collaboration.

**Information development and exchange**

INIBAP has an active global and regional information and documentation program. Several books, manuals, proceedings, factsheets, serials, etc. are published and distributed regularly. INIBAP publications are also available in CDROM and can be accessed through the INIBAP website. Moreover, two global databases are maintained at INIBAP Hq namely: MUSALIT (a bibliographic database on banana researches) and BRIS (database on banana researchers). On the otherhand, the network has the Regional Information System for Banana and Plantain – Asia and Pacific (RISBAP), which supports the global database, MUSALIT. The RISBAP Bulletin, a regional newsletter supported by INIBAP-AP and published at least three times a year, is another regional mechanism for improving the dissemination, utilization and access of information on banana and plantain in the region.


**Musa diversity in Southeast Asia - An analysis of data**

Olivier Guinard, Suzanne Sharrock*  
and Elizabeth Arnaud

**Introduction**

Southeast Asia and the Pacific is the centre of diversity of the genus *Musa*. This diversity includes a wide range of wild species, which are divided amongst the sections Australimusa, Callimusa, Rhodochlamys, Eumusa and a large number of different types of cultivated banana varieties which fall into various genome groups (AA, AAB, AAB etc).

This diversity provides the raw materials used by banana breeding programmes to develop new, improved high yielding varieties with enhanced capacity to withstand pest and disease attack. These improved varieties are starting to be introduced and grown in many countries in the Asia-Pacific region.

Due to the high levels of sterility in most cultivars, banana breeding is a complicated, time consuming and expensive task. For this reason, very few breeding programmes exist in the world, and most of the major programmes are located outside Asia. For this reason, there is a great interdependence between countries and regions for *Musa* germplasm.

**INIBAP’s role in Musa diversity management**

**Conservation**

INIBAP maintains the world collection of *Musa* germplasm. This collection is held *in vitro* at the INIBAP Transit Centre (ITC), which is located at the Katholieke Universiteit Leuven (KUL), Belgium. This collection of germplasm is held ‘in trust’ for the world community and ownership of the accessions in the collection remains with the country of origin. All material held in the world collection is provided to INIBAP under the terms and conditions of a Germplasm Acquisition Agreement (GAA) which confirms that the material will stay in the public domain, and will be made freely available for distribution on request. The world collection acts as a safety back-up, or duplicate

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This paper is a shortened version of a paper prepared by Olivier Guinard, an intern with the Quebec Ministry of International Relations as part of his internship with INIBAP. A copy of the full version of the paper is available from INIBAP on request.
collection for NARS, and accessions are available for repatriation, should they be lost from national collections.

**Collecting**

INIBAP supports germplasm collecting activities, with a particular focus on filling gaps in germplasm collections. In recent years, collecting missions have been held in China, Vietnam and Indonesia.

**Distribution**

All accessions in the world collection maintained by INIBAP are held *in vitro* and are routinely indexed for the presence of virus infections. In line with the Guidelines for the safe international movement of *Musa* germplasm, only those accessions in which no virus particles are found are made freely available for distribution. All germplasm is distributed under the terms and conditions of a Material Transfer Agreement which ensures that the germplasm stays in the public domain.

**Characterisation**

INIBAP carries out molecular and cytological analysis of all germplasm it maintains. This information is made freely available to users of the germplasm, as well as to germplasm curators and researchers in the country of origin of the germplasm. Such information thus adds value to the germplasm and supplements characterisation and evaluation data collected by users of the germplasm.

**Information management - the Musa Germplasm information System (MGIS)**

Following a request by *Musa* researchers and genebank curators, INIBAP has developed an information system which allows genebank curators to efficiently manage the information they generate about the accessions in their collections. As well as being a tool for curators, the MGIS also provides a mechanism by which information can be exchanged between curators. All data entered in MGIS remains the property of the country entering the data, but by sending updates to INIBAP, national data can also be incorporated into the global database. The global database is made available by INIBAP to participating institutes on CD-ROM and will shortly be available for free consultation on the internet.

MGIS presently contains passport data for 4810 accessions from 16 different institutes, and these include photographs for 763 accessions. Characterization data is available for 1745 accessions and agronomic evaluation data for 1643 accessions. MGIS is therefore a mine of
information on *Musa* germplasm and provides a unique resource for *Musa* researchers around the world.

**Analysis of MGIS contents**

MGIS is becoming increasingly widely used by curators around the world as a repository of information on *Musa* germplasm. It is therefore starting to provide a useful tool which can be used to carry out analyses at the global level. Through examining the contents of MGIS, information can be obtained, for example, on the extent of diversity being held in *ex situ* collections. Such information is essential in developing future collecting strategies and helping countries to rationalise *ex situ* collections, and also provides the base upon which national and regional conservation strategies can be developed.

**What is being conserved?**

A first analysis of the contents of MGIS, shows that the vast majority of accessions recorded by genebank curators are cultivated varieties. These make up around 80% of the accessions recorded in the database (Figure 1). These accessions cover reasonably well all the various genome groups (Figure 2).

**Figure 1.** Type of accessions recorded in MGIS.

**Figure 2.** Genome groups of cultivars recorded in MGIS.
Amongst the wild species, accessions of the section Eumusa, particularly *Musa acuminata* and *M. balbisiana* predominate, with wild species from the sections Australimusa, Rhodochlamys and Callimusa being generally poorly represented (Figure 3). A number of wild *Musa* species are not included in the database at all.

**Figure 3.** Distribution of wild accessions in MGIS according to sections of the genus *Musa*.

Although there are a number of accessions of *M. acuminata* recorded in the database, there is an uneven representation of the various subspecies. For example, only 4 accessions of Calcutta 4 (*M. acuminata* ssp. *burmannicoides*), the main source of black sigatoka resistance used by the banana breeding programmes, are recorded in germplasm collections. In addition, many accessions recorded as *M. acuminata* are unclassified at the subspecies level (Figure 4).

**Figure 4.** Subspecies of *Musa acuminata* in MGIS.
Analysis of national-level data in MGIS

Considering that the Asia Pacific region is the centre of diversity on Musa, it was decided to carry out a more detailed analysis of the data in MGIS originating from seven countries in this region. This preliminary analysis was carried out in order to identify gaps and inconsistencies in the data and to make recommendations towards future germplasm management strategies for the region. The analysis was based on the standard MGIS database, supplemented by searches made using the experimental MGIS web site. In addition, information about Musa diversity in each country was obtained from the literature, with particular use of the following publications: The records of Paul H. Allen (INIBAP/FHIA 1999), ASPNET meeting reports, Valmayor et al. 1990 and Banana Cultivar Names and Synonyms in Southeast Asia (INIBAP-ASPNET 2000). The countries included in the analysis were: Philippines, Thailand, Vietnam, Papua New Guinea, China, Malaysia and Indonesia.

Philippines

The Philippines Musa germplasm collection is maintained by the Bureau of Plant Industry, Davao National Crop Research and Development Centre (DNCRDC). This collection has been designated a regional collection of which 294 accessions are recorded in MGIS. Information on the country of origin is available for 78% of these accessions. According to information in MGIS, 43% of the accessions maintained in Davao originate from Philippines. The remainder originate from Malaysia, Thailand, PNG and Indonesia.

According to searches in the literature, 124 accessions which have been recorded as being present in Philippines are not included in the Davao collection. Of these, 38 can however be found in other collections (e.g. Honduras, INIBAP). Only 31 accessions from the Philippines have been duplicated in the international collection maintained by INIBAP.

An attempt was made to analyse the extent of diversity present in the Davao collection, but due to problems in the classification data entered in MGIS, this was not possible to do. Efforts are required to correct this data in the database.

Vietnam

Information is available in MGIS on the collection maintained at the Phu Ho Crop Research Centre. Data has been entered for 84 accessions,
of which 48 are duplicated in the international collection. For these accessions, molecular and cytological information is available from INIBAP. According to the data in MGIS, no wild *Musa* species are maintained in the Phu Ho collection, although several are reported in the literature as being present in Vietnam. One of the major problems encountered in analysing data from Vietnam related to the large number of synonyms that seem to exist (Figure 5). A further problem was the use of Vietnamese characters which cannot be read by other users of MGIS.

![Diagram of banana and plantain varieties](image)

**Figure 5. Ambiguous synonymical links in MGIS and literature.**

**Malaysia**

No records from Malaysia have been entered in MGIS and only a few cultivars originating from Malaysia, which are present in other collections around the world, are recorded in the database. These include 6 accessions which are recorded by INIBAP as being present in the international collection. None of the wide diversity of wild species from Malaysia is recorded in MGIS.
Indonesia

Information on the germplasm collection maintained by the Research Institute for Fruits (RIF) in Solok, Indonesia is available in MGIS. A total of 197 accessions have been recorded in the database. Following a literature search, 60 accessions known from Indonesia are not recorded in any collection in MGIS. Only 7 accessions from the RIF collection are duplicated in the international collection. An analysis of the extent of diversity present in the collection revealed that a wide range of cultivar genotypes and wild species are maintained in the genebank.

One problem regarding data from Indonesia related to the nomenclature used. For example, the accession Susu which is present in several collections, recorded as originating in Indonesia in MGIS, and is listed as an Indonesian accession by Valmayor (1990), is not listed as Susu by RIF. Instead, the RIF collection lists: Susu olahan, Susu ternate and Klutuk susu. It is not clear which Susu is being referred to by the other collections. A similar problem exists with the accession Kepok.

Thailand

No data from Thailand has been recorded in MGIS. However, 37 accessions are present in the international collection originating from Thailand and many accessions are present in the regional collection in the Philippines. Many wild Musa species are known to exist in Thailand but none of these are recorded in MGIS.

Papua New Guinea

The national Musa germplasm collection is maintained by the National Agricultural Research Institute at Laloki. To date, only 39 out of a collection of 309 accessions have been recorded in MGIS. This lack of data relates to computer problems in PNG. However, more than 250 accessions from the collection are duplicated at both South Johnstone Research Station in Australia and in the international collection. Information about PNG accessions is therefore available from data entered by South Johnstone and INIBAP. Such data includes characterisation data as well as molecular and cytological data. An analysis of the extent of diversity included in the collection shows that both cultivars and wild species are well represented and the diversity reflects that found in the country as a whole.
China

Information on Chinese accessions is available from the South China Agricultural University (SCAU). Information on 98 accessions is available and these consist mainly of AAA and ABB cultivars. No accessions from China have been sent to the international collection.

Conclusions and recommendations

During this first analysis of data in MGIS, some immediate difficulties were identified:

- Lack of data – especially related to origin of accessions.
- Searches by name were difficult due to the use of vernacular prefixes, such as Chuoi, Pisang, Kluai
- The use of special characters (Vietnamese) which could not be recognised by non-Vietnamese computers;
- Inconsistencies in the naming of wild species:
  - *Musa acuminata* ssp. *banksii*
  - *M. acuminata* ssp. *banksii*
  - *M. banksii*
  - Banksii
  - Etc.

As a result of this work, a number of recommendations were made:

- Efforts should be made to add data from important missing collections (Malaysia, Thailand)
- Existing data needs to be completed and corrected;
- NARS should make more effort to include wild species in germplasm collection
- Vernacular names should be standardised, and the use of prefixes should be avoided
- Full scientific names should be used for wild species. e.g. *Musa acuminata* ssp. *banksii*;
- Data on the origin of accessions should be completed to assist further analysis using GIS tools such as DIVA-GIS

Finally, it was recommended that, in recognition of the interdependence of countries for germplasm, and following the agreement that has been reached on the International Treaty for Plant Genetic Resources for Food and Agriculture, countries should share germplasm and related
information through INIBAP, making use of tools such as MGIS to facilitate this. The information available in MGIS should be used in the future to develop conservation strategies for Musa diversity.

References


Preliminary analysis of the *Musa* Germplasm Information System data for Southeast Asia using the Geographical Information System software DIVA-GIS

Olivier Guinard, Suzanne Sharrock* and Elizabeth Arnaud

Introduction

DIVA-GIS is a computer software developed by the International Potato Centre (CIP) and the International Plant Genetics Resources Institute (IPGRI) to map and analyse biological diversity. It was specifically designed to help spatially analyse the distribution of germplasm as well as their specific traits – morphological or genetic (Hijmans *et al.* 2001; Hijmans *et al.* 2002).

In 2002, INIBAP carried out a preliminary investigation into the potential use of DIVA-GIS as a tool to analyse data recorded in the *Musa* Germplasm Information System (MGIS). The benefits of carrying out GIS-based analysis are considered to be as follows:

At the global level:

- The ability to build maps showing the location of germplasm collections and provide access to environmental data at those sites through a single click;
- The ability to build maps showing the spatial distribution of *Musa* diversity, at the district, national, regional or even global scale;
- Providing assistance in decision-making regarding collecting campaigns;
- Providing the capacity to analyse diversity distribution according to environmental factors;
- Establishing correlations between the geographical distribution of varieties and species and the distribution of the main pests and diseases;
- Associating environmental factors with specific genetic traits;
- Improving MGIS data by checking the integrity of location information in MGIS;

*Germplasm Conservation Scientist, INIBAP, Montpellier, France.

This paper is a shortened version of a paper prepared by Olivier Guinard, an intern with the Quebec Ministry of International Relations as part of his internship with INIBAP. A copy of the full version of the paper is available from INIBAP on request.
• Promoting the entry of data in MGIS.
At the national level:
• Checking whether the national collection represents the range of diversity in the country;
• Helping in the decision making regarding the acquisition or elimination of material;
• Visualising national diversity;
• Completion and validation of location coordinates.

Materials and Methods

Data conversion and entry into MGIS

Passport and characterisation data from accessions in the collections of South Johnstone Australia (SJR), the Indonesian Research Institute for Fruit (RIF) and the Vietnamese Phu Ho Fruit Crop Research Centre (PHU) were extracted from MGIS using an SQL query, generating a DIVA-GIS compatible dbase-IV file. These three collections were chosen because they contained precise latitude and longitude coordinates of the collecting sites of accessions as well as morph-taxonomic descriptions and agro-evaluation data related to the accessions.

Data from the more recent collecting missions in Indonesia and for China were also extracted from MGIS. These accessions did not have any associated location coordinates and were thus assigned coordinates using the ‘assign coordinates’ function of DIVA-GIS.

These accessions were appended to the original .DBF file, resulting in a file which contained information on 461 accessions, each of which had 76 types of data associated with them, including important information such as longitude and latitude of collecting site, passport data, as well as minimum descriptor data. This was the basic file from which data was imported to create maps using DIVA-GIS.

Results

Visualizing Musa distribution

A first map was generated to show the original location (collecting site) of accessions used in the study (Figure 1). This map also highlights the countries from which data was availability for use with DIVA. Countries with valid MGIS data are coloured green, while other countries with MGIS data but no collecting site coordinates were coloured grey.

Wild Musa accessions were then categorized and displayed on a map
Figure 1. Countries with data used for DIVA-GIS of *Musa* germplasm. Countries in green possess MGIS data with valid geographical coordinates and were directly entered into DIVA-GIS after an SQL query and verification and modification. Countries in grey harbour MGIS-entered accessions but do not have sufficient geographical positioning information to contribute to the DIVA-GIS analysis. All accepted accessions are displayed as yellow squares.

Figure 2. Section-level distribution of *Musa* germplasm in Southeast Asia. Circed distribution regions are adapted from previous publications (Champion 1967). The map shows the presence of a *Rhodochlamys* specimen (blue triangle) near the South China-Viet Nam border could bring the redrawing of the previously accepted area. The case is the same for *Callimusa* germplasm (orange square).
according to their respective taxonomic sections. The map (Figure 2) showed that recent collecting missions in China have revealed the presence of *Musa laterita* (Rhodochlamys) on the border of the Guangxi province of China and northern Vietnam, much to the east of where this species had been reported previously. An even more striking example is a *Musa coccinea* (Callimusa) accession reported in the Guangdong province of China, which if truly native, and not introduced, could expand the traditional distribution of the Callimusa section much to the northeast.

These first maps show the limited areas in which germplasm has so far been collected and for which relevant data is available. However, they also illustrate how DIVA-GIS can help in determining in which regions to organize future collecting missions, as well as providing a clear means to visualise the distribution of diversity in any given area.

**Georeferencing Musa characteristics**

Only relatively few of the accessions recorded in MGIS actually have both valid collecting site coordinates as well as morphological and agronomic traits associated with them. However, using available data, *Musa* accessions were classified according to their classes for each morphological trait entered in DIVA-GIS. Maps which showed obvious differences were retained (Figure 3 A-D). By superimposing maps showing environmental variables: soil type, altitude, ecoregion etc., it is easy to correlate specific germplasm-related traits with environmental or other factors. For example, if data were available, DIVA-GIS would provide an ideal tool to link pest and disease distribution and associate environmental factors with tolerance/resistance traits in germplasm.

**Assessing diversity richness**

DIVA-GIS has the capacity to analyse diversity in a number of ways (Hijmans et al. 2002). Generally, DIVA-GIS divides geographic areas into user-specified size square cells making up a grid. Using DIVA-GIS, the amount of diversity to be found within each grid square can be measured and maps produced indicating those areas of greatest diversity richness (either at species or cultivar level). Insufficient data is presently available in MGIS to create useful maps of this type, although initial studies based on available data indicate that hot spots of wild *Musa* diversity can be found on the northern coastal area of PNG and in the Guangxi region of China near the Vietnamese border. This result must of course be treated with caution at this stage, as
Figure 3. *Musa* morphological trit distribution in Southeast Asia. All characteristics included in the *Musa* accessions that contained data were displayed in DIVA-GIS and maps were selected on the basis of highlighting regional differences. (A) Sucker development. (B) Pseudostem aspect. (C) Fruit length. (D) Fruit pulp colour at maturity.

most “high richness” grid cells simply reflect the regions targeted by INBAP and their collaborators in collecting missions held in the past two decades.

With regard to diversity conservation, DIVA-GIS also contains a function that prioritizes areas of richness in order of decreasing importance. Briefly, the grid cell with the greatest number of distinct species is identified and ranked one, while the species it harbours are removed from the “total” list of species identified; a second grid-cell containing the largest number of distinct remaining species is ranked “2”, and so on. This type of analysis can be used to identify, for example, priority areas for *in situ* conservation.
**Associating accessions with geo-referenced climate data**

With DIVA-GIS, it is possible to associate accession-coordinates with geo-referenced climate data observed from 1961 to 1990 and available from the DIVA-GIS website. Through this feature, one can examine the specific growth environment of a particular accession with regards to mean annual rainfall, lowest and highest temperatures, average temperature, etc. It is also possible to visualize the climate spectrum associated with *Musa* occurrence. Using data related to wild accessions a map was created showing that wild *Musa* species mainly occur in locations where there is an average annual temperature of between 20 and 27 degrees Celsius and where there is 1300 to 4000 mm of precipitation. DIVA-GIS is also able to locate the areas of a defined

![Map showing climate prediction](image)

**Figure 4.** Climate envelope prediction of future favourable weather (2041-2060) for wild species of *Musa*. (A) Prediction of areas with matching climate for Southeast Asia (in yellow). Red shows areas that presently house hospitable climate for *Musa* but that are predicted to change. Green areas are new areas of favourable climate predicted to appear. (B) Same as (A), world view.
geographic location where climatic factors fit this range. Most of the regions that fit the climatic range are well known areas of Musa occurrence, with the exception perhaps of the western coast of India, where very few wild species of Musa have been reported.

It is also possible to forecast where the corresponding climate range will occur in the future (2041 to 2060), thanks to mathematical predictions based on data from the Intergovernmental Panel on Climate Change Data Distribution Centre (1999). When DIVA-GIS was interrogated to locate matching areas of climate with expected data for 2041-2060, the result was impressive: Figures 4a and 4b show that the better part of presently favourable areas for banana production in Asia will have disappeared (in red) whereas only very little will have appeared (in green) or been conserved (in yellow).

**Conclusions**

DIVA-GIS is a versatile tool and the variety of maps produced during the study reflects very little of the numerous capacities of this free software. However, from a Musa scientist’s standpoint, its exploitation is rather limited as incomplete and absent data remains problematic at this time. Malaysia, the Philippines, Thailand and most of Indonesia have no transferable records in MGIS. Many of the accessions recorded in MGIS are not the direct result of collecting missions and the exact locations of the original source of the accession is often not known to the genebank curator. Indeed, out of over 1500 accessions listed in MGIS as originating from Southeast Asia, only 461 records have valid collecting site coordinates. All these accessions were collected through INIBAP-sponsored collecting missions and represent specific countries (PNG, IDN, CHN, VNM) and regions (Figure 1). Therefore accessions are mainly grouped together and do not give a complete overview of the Southeast Asian Musa distribution.

When one counts the accessions in MGIS that have both coordinates and characterization data (only 274), it is obvious that more information is needed. When investigating morphological traits with regards to geographic distribution, the absence of data for all regions of central Southeast Asia (Philippines, northern Indonesia and Malaysia) made localising specific traits difficult. However, it was possible to discern some “regional” differences between PNG germplasm and south China/Vietnam germplasm. Considering the geographic distance between these accessions and the different environments in which they are growing, it is understandable that some traits would widely differ between these two regions.
The major problem in highlighting differences of morphological characteristics in DIVA-GIS has to do with the very nature of *Musa*. Indeed, phenoplasticity means that specimens of the same genetic makeup may develop very different morphological traits depending on the environment they are growing in. It is therefore possible that specimens from different regions may display distinct aspects, even though these differences are not attributable to genetic differences. It becomes increasingly apparent that the importance of “agronomic traits” will eventually outweigh that of “morphological characteristics”. Agronomic information is based on studies made on specimens of different genotypes at the same location (the collection they are held in). Agronomic traits also have the advantage of being quantitative (numerical) whereas morphology is generally assessed qualitatively (classes), so that agronomic data may increase the precision in DIVA-GIS statistical analyses.

Whereas there is still much work to be done before the potential uses of DIVA-GIS can be fully exploited, immediate benefits can already be considered. The predicted favourable climate map presented in Figure 4 is an interesting and striking way to encourage curators to submit data and could also provide a useful public awareness tool, highlighting the need for greater support to efforts involving *Musa* germplasm collecting and conservation.

**Acknowledgements:** Thanks are due to Luigi Guarino, Secretariat of the Pacific Community (SPC) for training INIBAP staff in the use of DIVA-GIS, and his kindness in answering our many questions about the software.

**References**


Intergovernmental Panel on Climate Change Data Distribution Center. 1999. Providing Climate Change and Related Scenarios for Impact Assessment. CD-ROM. Version 1.0. Climate Research Unit, University of West Anglia, Norwich, UK.
Using GIS to support germplasm conservation and use

Luigi Guarino* and Robert Hijmans

Plant genetic resources (PGR) management is a complex process that ranges from studying genetic diversity within a gene pool, to conserving this variation and using it to solve agricultural and development problems. Many activities in this process generate and/or require geographic data. Geographic information system (GIS) software can help manage and analyze such data, and thus make the whole process of PGR management more effective and efficient. GIS can analyse passport and characterization/evaluation data and combine it with spatial information on human population density, climate, topography and soil. These analyses are necessary for such important activities such as monitoring genetic diversity, selecting priority sites for collecting, designing in situ reserves and identifying priority material for use in breeding programmes.

IPGRI is developing innovative methodologies and tools to support the use of GIS in collaboration with national and international organizations. This includes the design, development, and distribution of low cost and easy to use software tools such as DIVA-GIS, a recently released software for spatial analysis of genetic resources data.

DIVA-GIS allows users to map and verify the coordinates of accessions, extract associated climate data, predict species distributions based on climate, identify diversity hotspots and map the distribution of material with specific characteristics. DIVA-GIS is available free of charge from http://diva-gis.org and copies of the user manual and a tutorial can be downloaded from the same site. Geo-referenced data on all countries, including climate, land use, population density and administrative boundaries is available from http://diva-gis.org/Data.htm.

DIVA-GIS has been used to analyze geographic patterns of diversity among wild species in the genepools of the potato, cowpea and groundnut. It is also being used at INIBAP for spatial analysis of the data in the Musa Germplasm Information System.

DIVA-GIS was developed by the International Potato Center (CIP)

*Plant Genetic Resources Adviser, SPC, Suva, Fiji.
and IPGRI, with major additional support from the System-wide Genetic Resources Programme (SGRP) of the Consultative Group on International Agricultural Research (CGIAR), and the Food and Agriculture Organization of the United Nations (FAO).

For further information on DIVA-GIS, contact Robert Hijmans at rhijmans@uclink.berkeley.edu or Luigi Guarino at luigig@spc.int. More information on these GIS activities is also available on-line at http://www.ipgri.cgiar.org/regions/Americas.

References


## Appendix 1: Programme of the 1st BAPNET Steering Committee meeting

### Sunday, 6 October
Arrival of participants

### Monday, 7 October

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>8:00 am</td>
<td><strong>Registration</strong> – CB Perez Conference Room, PCARRD</td>
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<tr>
<td>8:30</td>
<td><strong>Opening Ceremonies</strong></td>
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<tr>
<td></td>
<td>Invocation</td>
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<td></td>
<td>National Anthem</td>
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<tr>
<td></td>
<td>Introduction of Participants</td>
</tr>
<tr>
<td></td>
<td>Introduction of Conference Hosts</td>
</tr>
<tr>
<td></td>
<td><strong>Welcome Remarks</strong> Dr. Patricio S. Faylon Executive Director PCARRD</td>
</tr>
<tr>
<td></td>
<td>Message Sec. Estrella F. Alabastro DOST</td>
</tr>
<tr>
<td></td>
<td>Sec. Leonardo Q. Montemayor, DA</td>
</tr>
<tr>
<td></td>
<td>Dr. Agustin B. Molina Regional Coordinator</td>
</tr>
<tr>
<td></td>
<td>INIBAP-Asia Pacific</td>
</tr>
<tr>
<td></td>
<td><strong>Presentation of Awards</strong></td>
</tr>
<tr>
<td></td>
<td>Emcee: Dr. Jocelyn E. Eusebio Director, Crops Research Division PCARRD</td>
</tr>
<tr>
<td>10:30</td>
<td><strong>Coffee/Tea Break</strong></td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Group picture taking</strong></td>
</tr>
<tr>
<td>11:15</td>
<td><strong>Session 1: Presentation of Country Reports</strong></td>
</tr>
<tr>
<td></td>
<td>Rationale and Objectives Chair, BAPNET Steering Committee</td>
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<tr>
<td>11:15</td>
<td>Australia Mr. Robert Williams</td>
</tr>
<tr>
<td>11:35</td>
<td>Bangladesh Dr. Md. Shahudul Islam</td>
</tr>
<tr>
<td>11:55</td>
<td>Cambodia Dr. Men Sarom</td>
</tr>
<tr>
<td>12:25</td>
<td>Lunch Break</td>
</tr>
<tr>
<td>1:30 pm</td>
<td><strong>Continuation of Session 1</strong></td>
</tr>
<tr>
<td>1:30</td>
<td>China Dr. Xu Linbing</td>
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<tr>
<td>1:50</td>
<td>India Dr. M.M. Mustaffa</td>
</tr>
<tr>
<td>2:10</td>
<td>Indonesia Dr. I Djatnika</td>
</tr>
<tr>
<td>2:30</td>
<td>Malaysia Dr. Nik Masdek</td>
</tr>
<tr>
<td>2:50</td>
<td>Coffee/Tea Break</td>
</tr>
<tr>
<td>3:05</td>
<td>Papua New Guinea Mrs. Rosa Kambouou</td>
</tr>
<tr>
<td>3:25</td>
<td>Philippines Dr. Jocelyn E. Eusebio</td>
</tr>
<tr>
<td>3:45</td>
<td>Sri Lanka Dr. C. Kudagamage</td>
</tr>
</tbody>
</table>
Tuesday, 8 October

8:30 am Secretariat of the Pacific Community
8:50 Taiwan Banana Research Institute
9:30 Coffee/Tea Break
9:45 Session 2: INIBAP Programs and Technical Presentations

Tuesday, 8 October

4:05 Thailand Dr. Prasert Anupunt
4:25 Vietnam Dr. Ho Huu Nhi
7:00 pm Welcome Cocktails/Dinner w/ Cultural Show hosted by PCARRD

Tuesday, 8 October

8:30 am Secretariat of the Pacific Community
Mr. Tom Osborn
8:50 Taiwan Banana Research Institute Dr. S.C. Hwang
9:30 Coffee/Tea Break
9:45 Session 2: INIBAP Programs and Technical Presentations
Dr. Agustin B. Molina
10:00 Technical Presentations on Musa Diversity in Southeast Asia and DIVA-MGIS Ms. Suzanne Sharrock Dr. Luigi Guarino
12:30 Lunch Break
1:30 pm Session 3: Workshop/Discussions Facilitator: Dr. Jaine C. Reyes, UPLB

Wednesday, 9 October

8:30 am Continuation of Session 3
12:00 nn Lunch Break
1:00 pm Continuation of Session 3
3:00 Coffee/Tea Break
3:30 Synopsis of Workshop Election of New Chairman and other Administrative Matters Dr. Patricio S.Faylon

Wednesday, 9 October

8:30 am Continuation of Session 3
12:00 nn Lunch Break
1:00 pm Continuation of Session 3
3:00 Coffee/Tea Break
3:30 Synopsis of Workshop Election of New Chairman and other Administrative Matters Dr. Patricio S.Faylon

Thursday, 10 October

8:00 am Field Trip (UPLB/Manila)
7:00 pm Farewell Dinner w/ Cultural Show hosted by DA-BAR
Closing Ceremonies Special number PUP Dance Troupe

Thursday, 10 October

8:00 am Field Trip (UPLB/Manila)
7:00 pm Farewell Dinner w/ Cultural Show hosted by DA-BAR
Closing Ceremonies Special number PUP Dance Troupe

Message
Dr. Eliseo R. Ponce Director, DA-BAR
Programme

Sec. Estrella Alabastro
DOST

Symbolic Presentation of Workshop
Dr. Patricio S. Faylon
Dr. Eliseo R. Ponce

Output by
PCARRD & DA-BAR
to INIBAP

Message of
Dr. Ahmad Dimyati rep. by
New BAPNET Chair
Dr. I. Djetnika

Special number
PhilRice Chorale

Emcee: Mr. Nicomedes Eleazar
Assistant Director, DA-BAR

Friday, 11 October   Departure of participants
# Appendix 2: 1st BAPNET Steering Committee meeting participants

**BAPNET SC Members**

<table>
<thead>
<tr>
<th>Country</th>
<th>Participant Name</th>
<th>Position</th>
<th>Institution</th>
<th>Address</th>
<th>Contact Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
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</tr>
<tr>
<td>Bangladesh</td>
<td>Dr Md. Islam Shahidul</td>
<td>Director General</td>
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<td></td>
</tr>
<tr>
<td>Cambodia</td>
<td>Dr Men Sarom</td>
<td>Director</td>
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<td>Prateah Lang, National Road #3 Dangkor, Phnom Penh, Cambodia (P.O. Box 01, Phnom Penh, Cambodia) Tel: (855-23) 219692 to 94 Fax: (855-23) 219800 Email: <a href="mailto:msarom@cardi.org.kh">msarom@cardi.org.kh</a></td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>Dr Xu Linbing</td>
<td>Vice Director, Agronomist</td>
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<td>National Research Centre on Banana (ICAR)</td>
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</tbody>
</table>
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Fax: (84-4) 8613937
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Ms Versalynn N. Roa
Ms Maria Angeli Maghuyop

PCARRD
Ms Edna Anit
Mr Angelito Carpio
Ms Susan Ilao
Mr Joselito Payot
Appendix 3: Awards

THE INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN
ASIA PACIFIC NETWORK

Presents this

Plaque of Appreciation

to

Lapanday Agricultural and Development Corporation

In recognition of its cooperation and active participation in INIBAP programmes/activities such as the International *Musa* Testing Programme III and the 3rd International Workshop on *Mycosphaerella* leaf spot diseases of bananas in May 2002;

In grateful appreciation of its financial donation in support to the study of variability of leaf spot disease in the Philippines and supporting the publication of the proceedings of the 3rd International Workshop on *Mycosphaerella* leaf spot diseases of bananas in May 2002;

In recognition of its generous participation in helping the local small-scale banana industry by producing tissue culture planting materials of local cultivars as well as selected INIBAP IMTP improved varieties at reasonable price and for providing free training on nursery management to DMM MSU researchers.

This Plaque of Appreciation is given this 7th day of October 2002 in PCARRD, Los Baños, Laguna, Philippines.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP-Asia Pacific

EMILE A. FRISON
Director
INIBAP
THE INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN
ASIA PACIFIC NETWORK

Presents this

Plaque of Appreciation

to the

Philippine Council for Agriculture, Forestry
and Natural Resources Research and Development
(PCARRD)

In recognition of its strong commitment in banana R&D, for its cooperation with
INIBAP, and for sponsoring and hosting the INIBAP office for Asia and the Pacific
in the Philippines;

In appreciation for hosting and co-hosting the International Workshop on
Identification of Genetic Diversity of the Genus Musa on 5-10 September 1988,
the Regional Consultation on Banana and Plantain R&D networking, the first
Consultation Workshop of the Regional Information System for Banana and
Plantain on 1-3 April 1996, Regional Workshop on Disease Management of
Banana and Citrus on 14-16 October 1998 and this year the first Banana Asia
Pacific Network Steering Committee Meeting on 7-10 October 2002.

In acknowledgement of its vital role and contribution to the Regional Information
System on Banana and Plantain – Asia and the Pacific.

This Plaque of Appreciation is given this 7th day of October 2002 in PCARRD,
Los Baños, Laguna, Philippines.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP-Asia Pacific

EMILE A. FRISON
Director
INIBAP
THE INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN
ASIA PACIFIC NETWORK

Presents this

**Plaque of Appreciation**

to the

Department of Agriculture
Bureau of Agricultural Research
(DA-BAR)

In recognition of its strong commitment in banana R&D, for its cooperation and annual financial contribution to IPGRI/INIBAP towards the conservation, characterization and evaluation of *Musa* germplasm in the Philippines;

In sincere appreciation to its strong support to the national banana development by funding a 3-year program to accelerate the evaluation, dissemination and adoption of improved *Musa* varieties through the National Repository, Multiplication and Dissemination programme;

In appreciation for co-hosting this year the first Banana Asia Pacific Network Steering Committee Meeting on 7-10 October 2002.

This Plaque of Appreciation is given this 7th day of October 2002 in PCARRD, Los Baños, Laguna, Philippines.

AGUSTIN B. MOLINA
Regional Coordinator
INIBAP-Asia Pacific

EMILE A. FRISON
Director
INIBAP
THE INTERNATIONAL NETWORK FOR THE IMPROVEMENT OF BANANA AND PLANTAIN  
ASIA PACIFIC NETWORK  

Presents this  

Plaque of Special Recognition  

to  

Dr. Ramon V. Valmayor  

In recognition of his outstanding contribution to international banana research and especially his dedication to supporting activities in the Asia-Pacific region, where he became the founding Coordinator of the Asia-Pacific regional network in 1991.  

In sincere appreciation of his seven years as INIBAP Regional Coordinator for Asia and the Pacific, during which time he worked untiringly to promote banana research and collaboration in the region, and the two subsequent years providing continued support to INIBAP as Honorary Research Fellow.  

In acknowledgement of his dedication to research on the taxonomy and classification of Musa, and particularly his contribution to the regional workshop on ‘Banana cultivar names and synonyms in Southeast Asia’. For his efforts in initiating a series of collecting missions covering Vietnam, Southern China, Indonesia and N.E. India, resulting in the discovery of many undescribed banana species and cultivars.  

In tribute to his many publications and articles on Musa, and especially in recognition of his recent impressive publication, “The Wild and Cultivated Bananas of the Philippines”, an important reference work for the international Musa community.  

This Plaque of Special Recognition is given this 7th day of October 2002 at PCARRD, Los Baños, Laguna, Philippines  

AGUSTIN B. MOLINA  
Regional Coordinator  
INIBAP-Asia Pacific  

EMILE A. FRISON  
Director  
INIBAP
The Banana Asia Pacific Network

Presents this

Pisang Raja Award

to

Suzanne Sharrock

In recognition of her tireless efforts towards Musa collecting and conservation, which began in 1988 and 1989 when she lead, on behalf of IBPGR, four collecting missions in Papua New Guinea assembling more than 200 accessions.

In sincere appreciation of her collaboration, as INIBAP Germplasm Conservation Scientist, with INIBAP-ASPNET and now BAPNET, her generosity in sharing her expertise on Musa conservation, guiding people through the maze of Musa taxonomy and making people aware of the importance of conserving Musa diversity.

In acknowledgement of her striving to establish a consensus on the classification of Musa varieties which is a crucial step toward a better utilization of genetic resources in breeding programmes. One of her contributions in that respect is the publication of a catalogue of Musa diversity, Musalogue. In recognition of her forward-thinking and planning to link the MGIS database to a Geographical Information System which aims to help researchers in their analyses and decision-making on genetic resources and their conservation.

And thanking her for her never-ending enthusiasm and sense of humour that bridge any divisions in the multicultural environment of banana research and development.

This Pisang Raja Award is given this 7th day of October 2002 at PCARRD, Los Baños, Laguna, Philippines.

PATRICIO S. FAYLON
Chair, BAPNET

AGUSTIN B. MOLINA
Regional Coordinator, INIBAP-AP

EMILE A. FRISON
Director, INIBAP
## Appendix 4: List of acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<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>AICRP</td>
<td>All India Coordinated Research Project</td>
</tr>
<tr>
<td>APAARI</td>
<td>Asia-Pacific Association of Agricultural Research Institutions, India</td>
</tr>
<tr>
<td>ASPNET</td>
<td>Asia and Pacific Network</td>
</tr>
<tr>
<td>BAPNET</td>
<td>Banana Asia Pacific Network</td>
</tr>
<tr>
<td>BBTV</td>
<td>Banana Bunchy Top Virus</td>
</tr>
<tr>
<td>BIC</td>
<td>Banana Industry Committee</td>
</tr>
<tr>
<td>BIP</td>
<td>Banana Improvement Program</td>
</tr>
<tr>
<td>BIPB</td>
<td>Banana Industry Protection Board, Australia</td>
</tr>
<tr>
<td>BLS</td>
<td>black leaf streak</td>
</tr>
<tr>
<td>BOI-DTI</td>
<td>Board of Investments - Department of Trade and Industry, Philippines</td>
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<tr>
<td>BPI-DNCRDC</td>
<td>Bureau of Plant Industry - Davao National Crop Research and Development Center, Philippines</td>
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<tr>
<td>BBrMV</td>
<td>Banana Bract Mosaic Virus</td>
</tr>
<tr>
<td>BS</td>
<td>black sigatoka</td>
</tr>
<tr>
<td>BSV</td>
<td>Banana Streak Virus</td>
</tr>
<tr>
<td>CABI</td>
<td>CAB International, UK</td>
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<tr>
<td>CARDI</td>
<td>Cambodian Agricultural Research and Development Institute</td>
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<tr>
<td>CIP</td>
<td>International Potato Center, Lima, Peru</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>CPBQA</td>
<td>Coastal Plains Banana Quarantine Area</td>
</tr>
<tr>
<td>CPBQS</td>
<td>Coastal Plains Banana Quarantine Stations</td>
</tr>
<tr>
<td>CRCTPP</td>
<td>Cooperation Research Centre for Tropical Plant Protection, Australia</td>
</tr>
<tr>
<td>DA-BAR</td>
<td>Department of Agriculture - Bureau of Agricultural Research, Philippines</td>
</tr>
<tr>
<td>DMI</td>
<td>demethylase inhibitor</td>
</tr>
<tr>
<td>DNA</td>
<td>deoxyribonucleic acid</td>
</tr>
<tr>
<td>DOA</td>
<td>Department of Agriculture, Sri Lanka</td>
</tr>
<tr>
<td>DOST</td>
<td>Department of Science and Technology, Philippines</td>
</tr>
<tr>
<td>DTI</td>
<td>Department of Trade and Industry, Philippines</td>
</tr>
<tr>
<td>ELISA</td>
<td>enzyme-linked immuno solvent assay</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations, Italy</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>Foc</td>
<td><em>Fusarium oxysporum</em> f.sp. <em>cubense</em></td>
</tr>
<tr>
<td>FRAC</td>
<td>Fungicide Resistance Action Committee</td>
</tr>
<tr>
<td>FHIA</td>
<td>Fundacion Hondureña de Investigacion Agricola, Honduras</td>
</tr>
<tr>
<td>FSM</td>
<td>Federated States of Micronesia</td>
</tr>
<tr>
<td>ft</td>
<td>foot/feet</td>
</tr>
<tr>
<td>GAA</td>
<td>Germplasm Acquisition Agreement</td>
</tr>
<tr>
<td>GAAS</td>
<td>Guangdong Academy of Agricultural Sciences</td>
</tr>
<tr>
<td>GC</td>
<td>Giant Cavendish</td>
</tr>
<tr>
<td>GCTCV</td>
<td>Giant Cavendish Tissue Culture Variant</td>
</tr>
<tr>
<td>GDP</td>
<td>gross domestic product</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
<tr>
<td>ha(s)</td>
<td>hectare(s)</td>
</tr>
<tr>
<td>HVCC</td>
<td>High Value Commercial Crops</td>
</tr>
<tr>
<td>ICAR</td>
<td>Indian Council of Agricultural Research</td>
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<tr>
<td>IMTP</td>
<td>International <em>Musa</em> Testing Program</td>
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<td>INIBAP</td>
<td>International Network for the Improvement of Banana and Plantain, Montpellier, France</td>
</tr>
<tr>
<td>ITC</td>
<td>INIBAP Transit Centre, Leuven, Belgium</td>
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<tr>
<td>IPGRI</td>
<td>International Plant Genetic Resources Institute, Macaressa, Italy</td>
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<tr>
<td>IPM</td>
<td>integrated pest management</td>
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<tr>
<td>IRA</td>
<td>import risk analysis</td>
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<tr>
<td>kg</td>
<td>kilogram</td>
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<tr>
<td>KUL</td>
<td>Katholieke Universiteit Leuven, Belgium</td>
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<tr>
<td>m</td>
<td>meter</td>
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<tr>
<td>MARDI</td>
<td>Malaysian Agricultural Research and Development Institute, Serdang, Malaysia</td>
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<td>MGIS</td>
<td><em>Musa</em> Germplasm Information System</td>
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<td>MINT</td>
<td>Malaysian Institute for Nuclear Technology</td>
</tr>
<tr>
<td>mo(s)</td>
<td>month(s)</td>
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<tr>
<td>MUSALIT</td>
<td>INIBAP bibliographic database</td>
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<td>NARI-DLP</td>
<td>National Agricultural Research Institute - Dry Lowlands Programme, Papua New Guinea</td>
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<tr>
<td>NARRDS</td>
<td>National Agriculture and Resources Research and Development System</td>
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<td>NARS</td>
<td>National Agricultural Research System</td>
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<td>NGO</td>
<td>non-government organization</td>
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<td>NQ</td>
<td>North Queensland</td>
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<td>NRRCB</td>
<td>National Research Centre for Banana</td>
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<tr>
<td>NSW</td>
<td>New South Wales</td>
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<tr>
<td>NT</td>
<td>Northern Territory</td>
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<tr>
<td>PAU</td>
<td>Pacific Adventist University, Papua New Guinea</td>
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<tr>
<td>PAPGRENP</td>
<td>Pacific Agricultural Plant Genetic Resources Network</td>
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<td>PCARRD</td>
<td>Philippine Council for Agriculture, Forestry and Natural Resources Research and Development</td>
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<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
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<td>Acronym</td>
<td>Description</td>
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<tr>
<td>PGR</td>
<td>plant genetic resources</td>
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<td>PJB</td>
<td>Pisang Jari Buaya</td>
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<td>PNG</td>
<td>Papua New Guinea</td>
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<td>PROMUSA</td>
<td>Global Programme for <em>Musa</em> Improvement</td>
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<tr>
<td>QABC</td>
<td>Queensland Agricultural Biotechnology Centre</td>
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<tr>
<td>QBAN</td>
<td>Quality Banana Approved Nursery</td>
</tr>
<tr>
<td>QDPI</td>
<td>Queensland Department of Primary Industry</td>
</tr>
<tr>
<td>QHI</td>
<td>Queensland Horticulture Institute</td>
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<td>QUT</td>
<td>Queensland University of Technology</td>
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<tr>
<td>RAPD</td>
<td>random amplified polymorphic DNA</td>
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<tr>
<td>RC</td>
<td>Regional Coordinator</td>
</tr>
<tr>
<td>RIF</td>
<td>Research Institute for Fruits</td>
</tr>
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<td>RISBAP</td>
<td>Regional Information System for Banana and Plantain - Asia and the Pacific</td>
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<tr>
<td>sp/spp.</td>
<td>species</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>research and development</td>
</tr>
<tr>
<td>RDE</td>
<td>research, development and extension</td>
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<tr>
<td>SCAU</td>
<td>South China Agricultural University</td>
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<tr>
<td>SCUs</td>
<td>state colleges and universities</td>
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<tr>
<td>SET-UP</td>
<td>Small Enterprise Technology Upgrading Program</td>
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<tr>
<td>SPC</td>
<td>Secretariat of the Pacific Community, Fiji</td>
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<tr>
<td>t</td>
<td>tonnes</td>
</tr>
<tr>
<td>TBRI</td>
<td>Taiwan Banana Research Institute</td>
</tr>
<tr>
<td>TCP</td>
<td>tissue culture plant</td>
</tr>
<tr>
<td>TBPA</td>
<td>Tully banana production area</td>
</tr>
<tr>
<td>UM</td>
<td>Universiti Malaya, Malaysia</td>
</tr>
<tr>
<td>Unitech</td>
<td>University of Technology, Papua New Guinea</td>
</tr>
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<td>UPM</td>
<td>Universiti Putra Malaysia</td>
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<td>UQ</td>
<td>Queensland University</td>
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<tr>
<td>USM</td>
<td>Universiti Sains Malaysia</td>
</tr>
<tr>
<td>VAM</td>
<td>vesicular-arbuscular mycorrhiza</td>
</tr>
<tr>
<td>VASI</td>
<td>Vietnam Agricultural Science Institute</td>
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<tr>
<td>VCG</td>
<td>vegetative and compatibility group</td>
</tr>
<tr>
<td>VVOB</td>
<td>Vlaamse Vereniging voor Ontwikkelingsamenwerkingen Technische Bijstand, Belgium (or Flemish Association for Development Cooperation and Technical Assistance)</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
<tr>
<td>YS</td>
<td>yellow sigatoka</td>
</tr>
</tbody>
</table>