ISHS/ProMusa symposium

*Bananas and plantains: Toward sustainable global production and improved uses*

Bahia Othon Palace Hotel, Salvador, Bahia, Brazil
10-14 October 2011

**Program and abstracts**

Co-organized by:
Acknowledgements

This ISHS/ProMusa symposium is sponsored by the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Bioversity International, Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Banco do Nordeste do Brasil (BNB) and Sociedade Brasileira de Fruticultura (SBF).

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The contribution of all who have worked so hard towards the success of this meeting is gratefully acknowledged.
ISHS/ProMusa symposium

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Program and abstracts
# Program

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*E.P. Amorim, J.A. dos Santos-Serejo, C. Fortes Ferreira and S.O. Silva* |
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*R. Ortiz* |
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*S. Uma, M.M. Mustaffa, R. Thangavelu, R. Menon and P. Patil* |
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*S. Goigoux, F. Salmon and F. Bakry* |
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*J.F. Aguilar Morán* |
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*S. Uma, M.M. Mustaffa, K. Arun, M.S. Saraswathi, S. Backiyarani and P. Durai* |
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*K. Tomekpe and L. Sadom* |
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* C. Jenny, Y. Holtz, J.P. Horry and F. Bakry |
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* J. Daniells, V. O'Keefe, H. Smyth, K. Gething, K. Fanning and P. Telford |
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* R.N.G. Miller, M.A.N. Passos, F.L. Emediato, V.O. Cruz,  
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* J. Dale, H. Khanna, R. Harding, J-Y Paul, B. Mlalazi, J. Kleidon,  
P. Hoang, D. Becker, J. Daniells, P. Deo, D. Catchpoole, J. Geijskes,  
A. James, F. Banks, G. Arinaitwe and W. Tushemeyerwe |
| 15:00-15:15| Mining of *Musa* ECT Databases for the Development, Validation and Characterization of EST-SSRS  
* S.Backiyarani, S. Uma, Varatharaju, P. Shobana, M.S. Saraswathi and P. Sundararaju |
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* D. Talengera, W. K. Tushemeyerwe, G.T.S. Beemster, D. Inzé and K. Kunert |
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* S.Backiyarani, S. Uma, G.Arunkumar, M.S.Saraswathi and P. Sundararaju |
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<td>SSR Mining in 454 Transcriptome Sequencing-Derived <em>Musa acuminata</em> Unigenes</td>
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<td>17:05-17:10</td>
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<td><em>F.L. Emediato, M.A.N. Passos, C. de Camargo Teixeira, G.J. Pappas Jr. and R.N.G. Miller</em></td>
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<td>D. Dufour, O. Gibert, M. Reynes, A. Giraldo, A. Escobar and A. González</td>
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<td>J.A. Santos-Serejo, E.H. Souza, F.V.D. Souza and E.P. Amorim</td>
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<td>J.W.H. van der Waal and R.J.R. Moss</td>
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<td>G.A. Woldie</td>
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*B. Ekesa, C. Miroir, G. Blomme, I. Van den Bergh and M.W. Davey* |
| 11:50-11:55 | Mycosphaerella Leaf Spot Diseases and Their Effects on Banana Post-Harvest Quality  
*L. Saraiva, B. Cordenunsi and M. Chillet* |
| 11:55-12:00 | Acceptance of Banana Cultivars Resistant to Black Leaf Streak by Consumers of the Brazilian Northeast Region  
*D.S. Garruti, M.L. Matias, H.V.V. Facundo and M.A.A. Da Silva* |
| 12:00-12:05 | Preliminary Study on the Potential of Banana Sap as a Dyeing Agent for the Adinkra Industry in Ghana  
*B.M. Dzomeku and O.K. Boateng* |
| 12:05-12:10 | Selection of Banana Hybrids for Ornamental Purposes  
*J.A. Santos-Serejo, F.V.D. Souza, E.P. Amorim, J.R. Silva Filho and D.S. Costa Jr* |
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*M. Dita, H. Garming, I. Van den Bergh, C. Staver and T. Lescot* |
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| 14:45-15:00 | Introduction to workshops |
| 15:00-15:15 | BREAK |
# Workshop

**Knowledge Sharing**

*Convenors: Anne Vézina and Inge Van den Bergh*

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A. Vézina, R. Roviglioni and I. Van den Bergh               |
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**Thursday, 13 October 2011**

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Future Directions in *Musa* Genomics and Applications in Genetic Improvement

*Convenors: Nicolas Roux and Robert Miller*

Pests and diseases in bananas – Projecting the effects of climate change

*Convenors: Charles Staver, Miguel Dita and Luis Pérez-Vicente*

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*E.P. Amorim*
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*D.H. Reinhardt and J.A. dos Santos-Serejo*

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  *D.W. Turner*

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- Growth Promotion in Micropropagated Banana by Rhizobacteria

  *E.M. Ramos, K.G. Viana Cardoso, K. Sírio Araújo, H.S. Alves Silva, A. Vilar Trindade and F. Haddad*

- Growth and Production of Banana Cultivars in the Brazilian Organic System in Three Cultivation Cycles

  *A.L. Borges, T. de Souza Profeta, J.C. da Silva Santos and C.A. da Silva Ledo*

- Production of Banana Genotypes under Subtropical Conditions in the Ribeira Valley, São Paulo, Brazil


- Potential Impact of Climate Change on Banana and Plantain Pests and Diseases in Cuba

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Opening Keynote: Panorama of the Banana Industry in Latin America and the Caribbean Islands

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Keywords: Musa, production, markets, institutes, research, perspectives

Natural product of excellent nutritional value and consumed in volume almost equivalent to some important staple crops, banana is the most important fruit in the world, and so it is in Latin America, where there are large producers such as Brazil, Mexico and Colombia, and some exporters of excellence such as Ecuador and Costa Rica. The banana industry in Latin America and the Caribbean islands is very diverse, going from a wide range of small growers mostly focused towards local and regional domestic markets, up to large plantations run by big companies with a few of them dominating the international market. And so diverse are the environmental conditions of the production areas, from subtropical to tropical ones, with a range from very humid to rather dry climates, from lowlands to highlands. Even though very few cultivars are destined for export, many different cultivars are being grown for national markets by using characteristic crop management practices which have more and more been directed to reduction of the use of chemical inputs. Equivalent to its importance, this crop has received the attention from many research institutes and organizations in many countries, with special evidence by Corbana in Costa Rica, Bioversity in several Caribbean Islands and Costa Rica, Inifap in Mexico, Ciat and Corpoica in Colombia, Inia in Venezuela, Minag and its several institutes in Cuba, Inia in Peru, Inta in Argentina and Embrapa and some other organizations, such as Epagri, in Brazil. Most of these entities are joined and work together in the MUSALAC network. Some of their main banana and plantain R&D strategies and recent advances will be summarized, with special attention to new cultivars, pest and disease control practices and crop management systems. The main present constraints of this industry demanding focused R&D and other strategic efforts of all players involved will be addressed, among those the possible impacts of climate change and changing consumer habits.
Keynote: Crop Physiology and Cultural Practices - A Synergy in Banana and Plantain (Musa spp.)

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Keywords: Agronomy, irrigation, water relations, evaporation

Knowledge of crop physiology can inform choices made about cultural practices. In the case of irrigation and water relations what we know about the physiology of bananas and plantains provides differing views on how the plant or crop system might be made more efficient. This review examines the methods used to determine the ‘reference evaporation’ for bananas and concludes that on most occasions bananas and plantains use less water than the evaporation from a class A pan evaporimeter. Differences between the tropics and subtropics are not always consistent. There are different ways of estimating the amount of water needed for a desired yield and this makes it difficult to draw generalizations about a crop factor.

There is a need to integrate knowledge of the physiology of water relations in bananas in a quantitative way so that the importance of each process can be evaluated in each situation. Then informed choices can be made and options selected that match the range of environments in which bananas and plantains are grown.
Tissue Culture Banana for Smallholder Farmers: Lessons Learnt from East Africa

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Keywords: Banana seed system, Burundi, Kenya, market pathway, Musa, Uganda

Tissue culture (TC) plants are pest- and disease free-planting material. There are many benefits from using TC plants, such as more uniform growth, and faster and bigger yields. The adoption of TC technology is still relatively low in East Africa, although booming under impetus from the private sector. TC technology can help banana farmers evolve from subsistence to income generation. A key threat to sustainable commercial TC plant production is the lack of implementation of quality standards and plant health certification. Such conditions are especially important to avoid spread of viruses, otherwise easily transmitted through TC plantlets. TC plant nurseries are essential, as they act as a distribution hub connecting TC producers to the farmers. However, TC nurseries in East Africa face many challenges. Relationships between TC producers and nurseries are often suboptimal, especially related to timing, quality and quantity of plantlet supply. At the nursery level, there are three main operational issues: water access, credit and transport of plantlets. The lack of sustainable market pathways to deliver the plants to the farmer constrains the commercial TC sector. Especially in Burundi and Uganda, outlet markets for TC plantlets are mainly governmental and non-governmental organizations, a situation which seems unsustainable in the long term. Empowering banana farmers into groups is an attractive strategy, because of increased buying and selling power, reduction in economic and social risk, increased economies-of-scale, and increased access to credit and inputs in the case of formally certified groups. Distribution of superior planting material will not in itself ensure a good crop. Smallholder farmers are constrained by factors such as a lack of land, capital, access to technology and good marketing infrastructure. As such, efficient distribution systems will need to deliver the TC plants as part of a package, including training and access to microcredit. TC banana plantlets
come at a cost, and might not be economically viable throughout all banana-producing areas in East Africa. Despite a booming commercial sector, there is only anecdotal evidence that farmers adopting TC bananas benefit in terms of higher yields and household incomes. Sound socio-economic analyses are crucial to guide policy strategies, learn from successes already achieved, and identify important constraints for a wider dissemination of TC banana in the region.

**Growth Promotion in Micropropagated Banana by Rhizobacteria**

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**Keywords:** Musa, plant growth-promoting rhizobacteria

*In vitro* propagation is the best way to achieve healthy banana plantlets. However, these plantlets are also aseptically free of beneficial microorganisms, which normally play an important role in plant growth and adaptation to stress conditions. This study aimed to select rhizobacteria strains able to promote growth of micro-propagated banana plantlets. A total of 302 rhizobacteria isolates were obtained, and their ability to produce indole acetic acid (IAA), phosphatase and siderophores was verified. Thirteen strains were selected and combined in a mix of three strains, based on ability to produce different compounds, and used to treat the banana explants. Plant height, dry weight of roots and shoots were evaluated after 30 days. The parameters were combined to establish a growth promoting index (GI) for each treatment. Treatment 2, composed by strains A130 and A140 (both IAA producing) and A137 (phosphatase producer), obtained the highest growth promotion (GI = 389), differing significantly (Tukey test $\alpha = 5\%$) from the control of untreated explants (GI = 300).
Growth and Production of Banana Cultivars in the Brazilian Organic System in Three Cultivation Cycles

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Keywords: Canavalia ensiformis, Arachis pintoi, cv. Maravilha

The organic system for banana in Brazil aims to contribute to improved cultivation using environmentally friendly, socially fair and economically viable approaches. The use of original propagation materials from plant species adapted to local edaphoclimatic conditions and tolerant to pests and diseases is a top priority. Therefore, in order to support organic system approaches, the object of the present work was to evaluate the growth and production of banana cultivars in three fruiting cycles. Six cultivars were studied: ‘Prata-Anã’ (AAB), ‘Caipira’ (AAA), ‘Thap Maeo’ (AAB), ‘Maravilha’ (AAAB), ‘Pacovan Ken’ (AAAB) and ‘Tropical’ (AAAB), in spacing of 4 m x 2 m x 2 m, with 50 plants each. The organic management was carried out with green manures (Canavalia ensiformis and Arachis pintoi), organic compost, castor bean cake and wood ash in the same ratios for all three cycles, and natural phosphate only in the 1st cycle. The following variables were compared between cultivars in the 1st and 2nd cycles by the Scott Knott Test (5%), and in 3rd cycle and also between 2nd and 1st cycles by the Tukey Test (5%). The growth of banana is influenced by the genetic characteristics of the cultivar. Growth was evaluated by plant height (m), pseudostem diameter (cm), number of leaves during flowering, as well as fruit production, i.e., length (cm), diameter (mm) and weight (g) of fruits. Whereas ‘Pacovan Ken’ was considered the most vigorous banana (3.44 m tall, 21.5 cm pseudostem diameter and 12.1 leaves), ‘Maravilha’ had the highest yield (25.5 t/ha) and the largest fruits (135.4 g, 17.3 cm in length and 36.3 mm in diameter) compared with other cultivars in the 1st fruiting cycle. The cultivars presented higher growth and production in the 2nd cycle, from 28% to 87% increase in yield for ‘Tropical’ and ‘Thap Maeo’, respectively. However, yield reduced in the 3rd cycle, notably for ‘Tropical’, ‘Caipira’ and ‘Prata Anã’. However, despite a 24-% decrease in yield in the 3rd cycle, ‘Maravilha’ produced fruits of 126.0 g, 17.1 cm in length and 35.7 mm in diameter, being considered of top quality. Therefore, in the evaluation of the three cycles, ‘Maravilha’ presented the best performance in the organic system.

Acknowledgements: FAPESB grant
Production of Banana Genotypes under Subtropical Conditions in the Ribeira Valley, São Paulo, Brazil

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Keywords: Musa, breeding

The search for new cultivars combining resistance or tolerance to pests and diseases, high productivity and organoleptic characteristics similar to the traditionally grown crops is the major objective of banana breeding. This work aimed to evaluate the production of different banana genotypes under Ribeira Valley conditions, Brazil. The experiment was carried out in a randomized design with 20 treatments (banana genotypes) and eight repetitions. The hybrid genotypes were separated into two banana groups: AAAA (‘Bucaneiro’, ‘FHIA-02’ and ‘FHIA-17’) and AAAB, further subdivided in three types: Prata-like (‘Garantida’, ‘FHIA-18’, ‘Maravilha’, ‘PA42-44’ and ‘PA94-01’); Pacovan-like (‘Japira’, ‘Pacovan Ken’, ‘PV79-34’, ‘PV94-01’ and ‘Vitoria’); and Maçã-like (‘Tropical’, ‘YB42-03’ and ‘YB42-07’). These hybrids were compared with the cultivars ‘Grande Naine’ (AAA, Cavendish), ‘Prata-Anã’ (AAB), ‘Pacovan’ and ‘Yangambi’, which have vegetative, productive and sensorial characteristics similar to the evaluated hybrids. Over two production cycles, the following production parameters were evaluated: bunch fresh weight (kg), yield (t.ha⁻¹.year⁻¹), number of bunches, total number of fruits per bunch, fresh weight (kg), length (cm) and diameter (mm) of fruit of the 2nd hand. Data from these parameters were calculated according to confidence intervals, and separated into the different banana groups and types. The highest yields were observed in the second cycle for all tested genotypes. In AAA and AAAA group, ‘FHIA-02’ and ‘FHIA-17’ showed the highest productivity (31.5 and 30.7 t.ha⁻¹.year⁻¹, respectively). In AAB and AAAB group type Prata, ‘PA94-01’ and ‘FHIA-18’ stood out (21.6 and 21.3 t.ha⁻¹.year⁻¹, respectively), whereas in the Pacovan type, ‘PV94-01’ obtained a yield of 29.9 t.ha⁻¹.year⁻¹. ‘Yangambi’ was the most productive genotype in the Maçã type (20.8 t.ha⁻¹. year⁻¹). Based on the results, it can be concluded that the banana genotypes ‘FHIA-02’, ‘FHIA-17’, ‘FHIA-18’, ‘Garantida’, ‘PA94-01’, ‘Japira’, ‘Pacovan Ken’, ‘PV94-01’, ‘Vitoria’, ‘Yangambi’, ‘Tropical’ and ‘YB42-07’ have potential for cultivation in the Ribeira Valley, Brazil.
Potential Impact of Climate Change on Banana and Plantain Pests and Diseases in Cuba

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Keywords: Global climatic models, black leaf streak, BSV, CMV, thrips, aphids fruit diseases

Banana and plantain are important cultivated crops in Cuba. Banana pests and their management significantly constrain yields and increase production costs. Monthly and daily climatic anomalies of maximal, median and minimal temperatures, relative humidity and rainfall for A2 and B2 scenarios (SRES/IPCC, 2000) were predicted for the years 2030 and 2060, using the climatic global models ECHAM5/MPI, HADCM3, and the Regional Climatic Modelling System PRECIS (Centella 2010, INSMET, Cuba). These simulated climatic anomalies were used to estimate possible impacts on pests and diseases in twenty-four production sites throughout the country. The expected scenarios A2 and B2 for 2030 and 2060 comprise anomalies of temperatures in a range of +2.3 to +2.8°C, reduction of the median relative humidity, lengthening of the dry season together with periods of drought and diminishing annual rainfall. Under these scenarios, higher temperature will be more favourable for black leaf streak (BLS) development from December to March when low temperatures are currently unfavourable to BLS in most of the sites. Concomitantly, the lower relative humidity and rainfall will reduce the period of favourable conditions for BLS development and other foliar plant pathogens. Incidence of Colletotrichum musae, Fusarium pallidoroseum, Deightoniella torulosa and other fruit pathogenic fungi dependent on high relative humidity and rainfall for sporulation, dispersal and infection will be subject to less favourable conditions for their development, even though their incidence is more related to cultural practices applied to fruits than to climatic changes. Temperatures will be more unfavourable for Pentalonia nigronervosa, Aphis gossipy and Myzus persicae, but due to drier conditions, aphid and pseudococcid vectors of Cucumber mosaic virus and banana streak viruses respectively will enjoy better conditions for dispersal and transmission of these viruses. Drier conditions will contribute to the increase of flower thrips Frankliniella parvula, red mite Tetranychus tumidus and palm red mite Raoiella indica populations and their damage to the host plants.
Photosynthetic Performance of Banana Cultivar ‘Gros Michel’ under a Natural Shade Gradient

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Keywords: Light, photosynthesis model, stomatal conductance, shade acclimation

Bananas are frequently grown in coffee and cacao agroforestry systems. We asked whether tree shade affects leaf photosynthesis (An) beyond simply the effects of the reduction in light availability. Does the leaf compensate for lower light availability to achieve greater than expected leaf photosynthesis? In this study, banana photosynthetic performance at leaf level of ‘Gros Michel’ (AAA) in three levels of natural shade (25%, 50% and 75% of full solar irradiance) were compared to a near full sun control. Gas exchange measurements of light and CO₂ response-curves on the third leaf were conducted to estimate the parameters of a biochemical sub-model of An - potential light-saturated electron transport rate (Jmax), maximum carboxylation rate (Vcmax) and day respiration (Rd) standardized at 25°C. The mean parameters of photosynthesis varied under different levels of light availability. Jmax decreased with increasing shade, falling from 163 for full sun to 134, 124 and 95 µmolm⁻² s⁻¹ for 75%, 50% and 25%, respectively. Vcmax was reduced only with the heaviest shade from 104 µmolm⁻² s⁻¹ in full sun to 69 under 25% light, while no significant differences were found for Rd. Light response-curves showed a reduction of maximal An only under exposure to 50% and 25% full solar irradiance. No saturation value for the photosynthetic photon flux density is apparent in full sun or the 75% treatment, but the saturating photon flux density varied from 800-1000 µmolm⁻² s⁻¹ in the 50% and 25% treatments. Under all treatments, stomatal conductance for leaf-to-air vapour pressure deficit values above 1.5 kPa decreased. A coupled model of stomatal conductance and photosynthesis captured the diurnal patterns of CO₂ and H₂O exchange, resulting in good agreement with data. Actual photosynthesis during the afternoon tended to be 7-9% lower than predicted. Field measurements and simulations showed that only with 50% shade or more is leaf photosynthesis significantly reduced. Such data in conjunction with whole plant performance and indirect effects of shade on disease levels and nutrient cycles can be used to optimize productivity and ecological services in multi-strata agroforestry systems.
Growing Gros Michel Bananas with Coffee and Trees: Addressing Threats and Opportunities through Farmer Participatory Research

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Keywords: Agroforestry, Musa

Gros Michel bananas, preferred by consumers throughout Latin America and the Caribbean, are grown by smallholders in association with coffee and trees. With minimal labour and purchased inputs, bananas provide a monthly income to supplement the once-yearly coffee sales. Through a GIZ-funded grant, scientists from Bioversity, German universities and research and field organizations in seven pilot sites in Peru, Nicaragua, Honduras and Costa Rica are using a three phase approach to test strategies for the improvement of banana productivity and income: formal diagnostic studies of 30 farm households and banana marketing; four farmer meetings and farmer-conducted sampling of coffee, trees, bananas, nutrients and marketing to identify priorities; and participatory experimentation and learning groups for on-farm prototyping of alternative approaches to system improvement. Across pilot-zones, banana mat-density varied from 300-600/ha with 950-1200 pseudostems/ha. Tree density varied from 150-550/ha with available light ranging from 50-70% and 35-45% for banana and coffee. Nutrients applied to coffee varied from 0-14 bags/ha. Coffee and banana yields/ha ranged between 200-1500 kg green beans and 85-400 bunches. Land planted with coffee/banana varied from 1-12 ha/farm. Farmer priorities across zones were similar: tree, banana and coffee resource-partitioning; improved coffee and banana crop-nutrition; coffee pruning; Fusarium wilt management; and marketing for better banana prices. Farmer participation in prototyping has varied across the pilot sites from 30-90% of the original 25 group members in each community. A 25x25m redesign plot has been the focus of experiments on banana thinning and replanting, coffee pruning and tree-shade thinning. Nutrient balance calculations have led to proposals for alternative leguminous tree species, pruning and reduced nitrogen and increased potassium fertilization. Bunch number and quality is being monitored monthly in 1-2 fields/site to improve
business plans. Mapping the distribution of Fusarium wilt has motivated community-based efforts to limit disease spread and testing of alternative cultivars acceptable to markets.
Keynote: Control of Banana Diseases

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Keywords: Musa spp., Mycosphaerella, Fusarium, viruses

Diseases are the most important constraints to banana production across the world and, under some situations preclude growing bananas. Fungal leaf diseases (Mycosphaerella leaf spots and other leaf spots caused by Cladosporium, Cordana and Cloridium spp.) all pose serious threats. Vascular diseases, like Fusarium wilt (Fusarium oxysporum f. sp. cubense), Moko bacterial wilt (Ralstonia solanacearum race 2) and Xanthomonas wilt (Xanthomonas campestris pv. musacearum) pose a similar threat, as do viruses (banana streak viruses - BSV, Cucumber mosaic virus - CMV, Banana bunchy top virus - BBTV and Banana bract mosaic virus – BBrMV) and several fruit spots and rots (anthracnose, crown rot, diamond spot, Deightonella fruit speckle, gray spot and cigar-end rot). Considering that each disease has its own characteristics with respect to its control, it would be impossible to focus all of them as a whole. We will therefore review proposed future actions aiming at improvement or adaptation of disease control measures that address global issues of environmental preservation and sustainable food production. With regard to leaf spots, it is very important to implement effective control measures in conjunction with forecasting actions and integrated management, looking for alternative production systems such as agroforestry systems and approaches able to break epidemic cycles. From the research point of view, it is important to search for alternative products that are less environmentally aggressive than currently used pesticides. It is important also to focus on the micro- and macro-nutritional influences in controlling banana leaf spots. Additionally, developing biological control strategies present a very feasible approach to Fusarium wilt control. In relation to disease resistance, it is suggested to explore the development of triploid varieties, since they have characteristics that are required by consumers; to identify resistance genes in available Musa germplasm and transfer them using cisgenic techniques, in
order to avoid consumer pressure on banana varieties considered as genetically modified; to intensify the search for sources of resistance to viral diseases and other sanitary problems not covered by current banana breeding programs; and to intensify the search for clonal variants that show resistance without losing desirable commercial attributes. Additionally, it is critical to address concerns about threats from climate change, especially those that predict reductions in rainfall and increases in temperature, but keeping in mind, however, that co-evolution is the prevalent aspect within host-pathogen relationships.

A Historical Overview of the Appearance and Spread of *Musa* Pests and Diseases on the African Continent: Highlighting the Importance of Clean Planting Materials and Quarantine Measures

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**Keywords:** Banana bunchy top virus, banana streak virus, exotic *Musa* germplasm introduction, fungal leaf diseases, Fusarium wilt, nematode, weevil, Xanthomonas wilt

Bananas are not native to Africa. They evolved in tropical Asia, from Southwest India eastward to New Guinea. There is growing circumstantial evidence which suggests that the East African Highland banana (EAHB) and the tropical lowland plantain were cultivated on the African continent since before AD 0. It is likely that Arabian traders (from 600 AD) brought ABB, AB and dessert AAB bananas from India to the continent and that these were slowly diffused in East Africa. The main centres of diffusion, for bananas
introduced in colonial times, were botanical gardens (e.g. Zanzibar, Zomba in Malawi, Entebbe in Uganda and Amani in Tanzania). It appears that the very early introductions of EAHB and plantain arrived in Africa without many of the major pests and pathogens affecting them in Asia, at least those that cause conspicuous damage and for which recent records on the continent exist. A wide range of Musa pests (nematodes and weevils) and diseases (banana bunchy top, banana streak, fungal leaf spot diseases, Xanthomonas wilt and Fusarium wilt) currently threaten banana/plantain cultivation across the African continent with severe implications for smallscale banana farmers. Examples of introductions with planting material are numerous, highlighting the need to implement strict quarantine measures. For example, the first reports of Fusarium wilt in East Africa were apparently associated with workers returning to the region from Mauritius after World War II. In addition, the banana weevil was most likely introduced in Uganda around 1908 with imported banana plants, which had been established in the Botanic Gardens at Entebbe. This paper (i) gives a chronological overview of first reported observations of a Musa pest or disease in Africa; (ii) highlights specific examples where a pest or disease was introduced with planting materials; and (iii) gives recent examples of how a pest or disease spread to a new region though infested or infected planting materials.

**Systemicity of Xanthomonas campestris pv. musacearum after Inflorescence Infection in East African Highland Banana and ‘Pisang Awak’ in Uganda**

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**Keywords:** Xanthomonas wilt, disease incidence, incubation period

Xanthomonas Wilt caused by *Xanthomonas campestris* pv. *musacearum* (Xcm) indiscriminately attacks all banana cultivars. Systemicity studies of inflorescence infected ‘Pisang Awak’ (ABB) and East African Highland Banana (AAA-EA) in farmers’ fields revealed four infection stages: wilting male bracts, decaying rachis, premature fruit ripening and rotting bunch/plant death. At the male bract wilting stage, the bacteria were restricted to the upper parts of the true stem in ‘Pisang Awak’ plants. Thus cutting these plants at the pseudostem-base was recommended to prevent further spread. However, within
plant/mat dissemination of Xcm and time to symptom expression in ‘Pisang Awak’ and AAA-EA mats after floral infection is not known. Knowledge on the efficacy of the different floral entry routes for the bacteria is also lacking. Addressing these gaps could fine-tune existing control strategies. AAA-EA and ‘Pisang Awak’ plants were inoculated with Xcm \((1\times10^8)\) cfus/mL through female bract scars, male bract scars, male flower scars, a combination of male bract and flower scars and by cutting the male bud with a contaminated machete. Thirty plants per genotype and treatment were then monitored for disease symptom appearance during 24 months after inoculation. An additional 68 AAA-EA and 25 ‘Pisang Awak’ plants were sampled weekly (cord roots, corm, real stem/pseudostem sections, rachis, fruits and male bud) for subsequent laboratory analysis to assess the dissemination speed of Xcm. All floral entry routes resulted in disease, while the highest incidence was observed for combined male bract and male flower scar inoculations. The study confirmed the systemicity of Xcm, with the pathogen able to live in the mat/plant for long periods without causing disease. Thus, relying on disease symptom expression to manage Xanthomonas wilt is not sufficient. The long incubation period in the lateral shoots also explains the current resurgence of the disease in locations where the disease was thought to have been successfully eradicated. Sustainable management of the disease necessitates the development of diagnostic kits to detect latent infections.

**Good Cultural Practices for Banana Bunchy Top Disease Management: A Sustainable Option for Burundian Smallholders?**

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**Keywords:** Banana bunchy top, control options, cropping systems, farmer awareness

Banana bunchy top disease (BBTD), caused by the *Banana bunchy top virus*, was reported for the first time in Burundi in 1987. Ever since, the disease has continued its spread throughout the Rusizi valley, reaching ever-higher altitudes, as no specific measures are being taken for its control. Management of BBTD through symptom and vector identification and good cultural practices was evaluated during a 1-year period in an on-farm research-led trial at Munyika (Cibitoke Province, ‘Yangambi Km5’ monocrop). In addition, a
“new start” demonstration trial consisting of ‘FHIA-03’, ‘FHIA-17’ and ‘FHIA-23’ in vitro plants was established 60 m away from existing plantations. In parallel, two contrasting control sites (no awareness-raising, no cultural practices) within Cibitoke were identified (Mparambo II, ‘Yangambi Km5’ monocrop and Muyange, ‘Igisenyi’ and/or ‘Igitsiri’ intercrop) and BBTD incidence and severity recorded quarterly on all three sites. Results indicate that initial BBTD incidence varied from one site to another, with reduced incidence (9%) in ‘Igisenyi’/‘Igitsiri’ intercropping systems compared to ‘Yangambi Km5’ monocropping systems (31%). Furthermore, in Munyika, disease incidence was higher in the vicinity of households (26%) versus recent plantations (3%). Data collected shows that when good cultural practices are applied and adhered to, within a year, BBTD incidence can be reduced to acceptable levels in an existing plantation (26-8%) and in new plantations (3%, FHIA trial). Moreover, severity is equally reduced, highlighting that farmers are presently familiar with initial symptoms and regularly scout fields to eradicate diseased plants. However, adoption rates of proposed management practices underline that most farmers - despite awareness raising - are reluctant to uproot the entire mat (100% of farmers) or the diseased corm (79% of farmers) when a single plant manifests visible symptoms. Refusal to conform to proposed practices might prove to be a limiting factor to sustainable management of BBTD in Burundi.

**Effectiveness of Agro-Ecological Intensification Practices in Managing Disease Complexes in Smallholder Banana Systems in East Africa**

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**Keywords:** Agro-ecological intensification, disease/pest management, farming motivation and production systems

In Eastern Africa, banana, a key staple for 20 million people, suffers increasingly from pests and diseases. Population pressure has reduced farmers’ ability to access mulch and manure and to rotate crops and fallow fields. This, coupled with the nutrient outflow via increased banana sales has resulted in declining soil fertility. Few farmers use pesticides and mineral fertilizer due to high cost and limited availability. Agro-ecological intensification (AEI) is the harnessing of ecological processes to increase productivity of local resources-
labour, off-farm nutrients and sunlight to increase production and reduce losses to stresses, while preserving the environment. Effective deployment of AEI needs to be addressed for different production systems and conditions of market and input access. Homologue sites selected on the basis of agro-ecology, production systems and farming objectives were evaluated for the incidence of common pests and diseases. Interviews with 48 households in two production systems and agro-ecological zones documented knowledge for applying AEI, including identification of diseases. The interviews also inventoried available capital, labour, and land, including irrigation, manure and mulch. Elements of AEI were in use across sites. Subsistence farmers were constrained by lack of knowledge and resources, including labour, to effectively apply AEI practices, particularly households that sell their labour off farm. In contrast, semi-commercial farmers were motivated to seek and access knowledge and used their agricultural incomes to marshal resources such as labour to apply AEI. With regard to disease/pest symptoms, some farmers readily recognized certain diseases (e.g. Xanthomonas wilt), while others confused symptoms (Xanthomonas and Fusarium wilt). The study concludes that improved farmer knowledge and capacity for ecological reasoning will lead to more effective use of current on-farm resources for disease/pest and nutrient-cycle management. Households that sell their labour may have difficulty using labour-intensive AEI. Understanding ecology should allow more targeted use of labour for IPM and nutrient management.

Detecting *Fusarium oxysporum f. sp. cubense* Tropical Race 4 in Soil and Symptomless Banana Tissues

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**Keywords:** Panama disease

Tropical race 4 (TR4) of *Fusarium oxysporum f. sp. cubense* (Foc) is a quarantinable pathogen in many banana producing regions in the world. Preventing further spread where it is present (e.g. Australia, Taiwan and the Philippines) and precluding incursions into areas where it has not been observed (such as Africa, South and Central America and the Caribbean) is
critical for maintaining local and commercial banana production. Spread of Foc is facilitated by trading of symptomless, but infected banana planting material, by movement of machinery with adhering infested soil and even by traditional banana-based packing material. In this work, field banana samples from symptomatic and symptomless banana plants collected in Taiwan and Australia, as well as infested soils from The Philippines were analyzed by using a PCR-based detection tool. Independently of the developmental stage of the sampled banana plants Foc TR4 was detected in symptomatic or symptomless samples as well as in soils from the Philippines by conventional or nested PCR analyses. These results will be used to develop and implement quarantine strategies and support TR4 management.

Characterization of Musa germplasm for Resistance to Tropical Race 4 of Fusarium oxysporum f. sp. cubense

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**Keywords:** Panama disease, disease resistance

Tropical race 4 (TR4) of *Fusarium oxysporum* f. sp. *cubense* (Foc) presents a major concern for current banana production worldwide. Two strategies are critical for controlling this pathogen: a) preventing its spread to TR4-free areas and b) identifying resistant banana genotypes. The team has established and validated a reliable and rapid greenhouse bioassay, and used it to characterize TR4 resistance in eight banana genotypes ['Gros Michel’ (AAA); ‘Silk’ (AAB), ‘Prat’a (AAB), ‘Pahang’ (AA, *Musa acuminata* ssp. *malaccensis*), ‘CIRAD 930’ (AA, DH Pahang), ‘Matavi’a (ABB), ‘Banksii’ (AA) and ‘Tuu Gia’ (AA)], where ‘Grande Naine’ (AAA) was used as a susceptible control. All genotypes were highly susceptible, but ‘CIRAD 930’ and ‘Pahang’ showed partial resistance, evidenced by highly reduced rhizome discoloration. Subsequently, we evaluated a segregating population of ‘Pahang’ (N=80) and observed three phenotypic groups a) susceptible, b) moderately resistant and c) resistant. We concluded that the bioassay is a reliable method to screen banana germplasm for TR4 resistance under greenhouse conditions and that ‘Pahang’ is an important source of resistance to Foc TR4 that should be further explored.
A Survey on the Banana Germplasm Deployment System in Asia and the Pacific

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Keywords: Musa, banana tissue culture, BAPNET

Banana is a very important crop for food and income for the majority of Asians. However, pests and diseases are major threats to banana production, especially among small-scale farmers. One component of an integrated disease management strategy for bananas is the use of disease-free planting materials, particularly of tissue culture (TC) planting materials. The primary reasons for suggesting use of TC planting materials are to improve productivity and to manage banana diseases, especially those caused by viruses. A survey was conducted to look into the banana germplasm system profile of the 13 member countries of the Banana Asia-Pacific Network (BAPNET). Questionnaires were sent to collaborating research institutions to gather country information on banana farming-system, common cultivars and uses, planting materials often used by farmers, pests, diseases and other factors affecting farmer preference on choice of planting materials. The study reveals that most (87%) banana farms in Asia are backyard, small- and medium-scale farms producing local popular banana cultivars for the local market. Commercial farms (13%) in the region produce Cavendish type to supply the export market (Philippines and Taiwan) and big cities (Australia, India and China). While commercial farms commonly use TC, most small- and medium-scale banana farms in the region still use locally sourced banana suckers. TC planting materials, mainly of Cavendish varieties, are sold commercially in only seven countries in the region. The low uptake of TC technology by most small-scale growers is due to the high cost of TC planting materials, absence of a cost-effective supply and delivery mechanism, and lack of knowledge and capacities needed to grow TC planting materials. The study suggests the need for farmers’ education on the
use of TC as planting material and the establishment of an operational banana TC planting materials delivery system at affordable cost.

Vegetative Characteristics of Two Genotypes of the Banana Pome Subgroup under Different Irrigation Systems

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Keywords: Growth, genotypes AAB and AAAB, water distribution

Banana clones that are grown under different irrigation systems may differ among themselves concerning the expression of vegetative traits, even under the same crop conditions. This might result from variations of soil water application among the systems that affect root distribution patterns, the diffusive flux of nutrients in the soil and/or plant nutrition, with consequent changes in plant physiology, all of which could contribute to increased variability within and between genotypes. Thus, this study aimed to evaluate the vegetative characteristics of two banana genotypes of the Pome subgroup, in three production cycles under different irrigation systems in semi-arid conditions. Experimental design followed a randomized block with six treatments in a 3x2 factorial scheme: three irrigation systems (sprinkler, micro-sprinkler and drip) and two genotypes [‘Prata-Ana’ (AAB) and ‘PA42 44’ (AAAB)]. Four replicates were used, with six plants spaced 3.0 x 2.5 m per plot. Plant height, pseudostem circumference, number of living leaves, length and width of the third leaf, total leaf area and leaf area index were evaluated at flowering, and number of leaves were also evaluated at harvest time. Data were submitted to variance analysis. Since the interactions were not significant, the means of irrigation system factor were compared by Tukey test and genotype factor by the F test, both at 5% probability. Irrigation systems affected vegetative characteristics. The drip irrigation system provided lower growth as verified by height and circumference of pseudostem, for both genotypes, compared to sprinkler and micro-sprinkler irrigation systems.
Risk Assessment of Black Leaf Streak Based on Probability Models of Climatic Data Adjusted with Spline Functions

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Keywords: Banana, satellite image, Mycosphaerella fijiensis

Black leaf streak, caused by Mycosphaerella fijiensis Morelet, has been causing serious damage to banana crops in most banana-producing areas of the world and also losses in fruit yield and quality, resulting in significant financial losses. This disease affects the leaves, causing brown streaks and black, necrotic spots, which reduce green-leaf, photosynthetic area. Currently, the main methods of controlling the disease are fungicides and using more resistant varieties. As an alternative, an ex-ante risk-analysis can be considered, which may improve black leaf streak control. Thus, it is necessary to study the climatic conditions that favour the occurrence of the disease, with the aim of identifying regions and periods with conditions most favourable to its occurrence, increasing the chances of prediction and optimizing the frequency and also the range of fungicide applications. Moraes and collaborators (2005) have developed a deterministic model based on climatic conditions to predict the likelihood of a black leaf streak outbreak. This paper presents the development of a probabilistic model based on the use of cubic spline functions in order to estimate the risk of black leaf streak occurrence, based on plant and environmental intrinsic factors. A case study has been conducted by using the weekly disease and weather monitoring in a commercial banana crop located in Jacupiranga, Vale do Ribeira, Brazil. In the presented research, remote sensing has been used to generate maps that show the risk of black leaf streak occurrence. The methodology developed proved to be feasible and promising for detecting periods and places that favour the occurrence of black leaf streak. Results support the implementation of early-warning systems or disease management programs that minimize energy use, mainly due to reduced fungicide use, resulting in economic and environmental gains.
An Early-Warning System as a Tool to Control Mycosphaerella Leaf Spots in Banana Plantations of Small Farms in Southern Brazil

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Keywords: Mycosphaerella musicola, Mycosphaerella fijiensis, plant disease, spray efficiency

Banana is the main fruit produced in the southern coastal region of Santa Catarina State, Brazil. It is a crop typically grown by small farmers, employing mainly family labour, on a total estimated area of 8500 ha with an average plantation size of 6 ha. Due to the humid subtropical climate (Cfa) of the region, with cool winters and warm summers, most plantations are grown on hillsides to avoid frosts. The annual average temperature is 19°C and annual precipitation is 1600 mm. Mycosphaerella leaf spots caused by Mycosphaerella musicola and Mycosphaerella fijiensis can reduce crop yield and banana quality. Since November 2000, banana growers have been supported by an early-warning system to control Mycosphaerella leaf spots. This tracks the gross sum of the disease, timing of fungicide application and crop management recommendations. Weekly or fortnightly observations of selected banana plants allows data collection for calculating the gross sum, in seven different places, involving five municipalities and covering 2800 ha of plantations. Spraying is recommended when the gross sum is ascendant and above 800 points, and the forecast indicates warm and wet weather favourable to disease development. Recommendations of crop management involve adequate plant density, weed control, soil fertility and leaf removal. Banana growers that have followed the warning system reduced the number of fungicide applications to only three, compared to the previous six or seven. They also report the ability to offer fruit of such a quality that greatly facilitates market acceptance compared to other producers. The warning system has been an important tool to control Mycosphaerella leaf spots with reduced production costs and lower negative environmental impacts. However, some growers have failed to control Mycosphaerella leaf spots for different reasons, such as the use of inappropriate application equipment (e.g. backpack atomizers), uneven ground conditions within hilly plantations which reduce spraying efficiency (with tractor-mounted sprayers), incorrect ingredients and poor preparation of the spray mix, and abandoned or poorly managed neighbouring plantations causing constant
contamination. Hence, it is necessary to involve a greater number of farmers to make the system still more efficient.

Necrotic Leaf Removal: An Effective Method against the Effects of Sigatoka Leaf Spot Disease on the Green Life of Bananas

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Keywords: \textit{Mycosphaerella musicola}, green life, cultural practices

Banana fruits are often harvested and marketed in the green stage. Green Life (GL) is the number of days between harvest and the initiation of ripening process, representing the time available to commercialization. Caused by the fungus \textit{Mycosphaerella musicola} Leach, Sigatoka leaf spot disease (SLSD) is one of the main foliar diseases of banana production that leads to early ripening of fruit, thereby reducing its GL. The aim of this work was to determine whether removal of necrotic leaves could limit the effects of SLSD on fruit GL. Plants were classified according to four SLSD infestation levels, based on estimation of necrotic leaf area during fruit development. GL of fruits was measured at 13°C, simulating the storage conditions during shipping transport, in two different treatments: plants with no leaf removal and plants with necrotic leaves removed (1 month before harvest). For the above-mentioned assessments, 60 plants per treatment were identified during the horizontal finger stage of flowering and tagged during a 2-week period. All plants were assessed for SLSD (severity index and others parameters) every 3 weeks. The experiment was carried out during 4 months. Results showed that higher SLSD infestation levels were associated with lower GL values, reaching almost zero for the highest infestation level without leaf removal. However, when the necrotic leaves were removed, the reduction of GL decreased and the GL reached values greater than 40 days, for the highest infestation levels. Analyses of variance followed by Newman-Keuls tests (5% threshold) were carried out to compare different infestation levels among treatments. Whatever the level of disease severity, the removal of necrotic leaves 1 month before harvest limited considerably or even suppressed the effect of SLSD on fruit GL. Therefore, necrotic leaf removal represents a simple and effective cultural practice to enhance GL of exportable bananas in the absence of efficient chemical control.
The Use of *Bacillus subtilis* QST 713 and *Bacillus pumilus* QST 2808 as Protectant Bio-Fungicides in Conventional Application Programs for Black Leaf Streak Control

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**Keywords:** Lipopeptides, Serenade, amino-sugars, sonata, resistance, management

The protectant fungicides Serenade®, based on the *Bacillus subtilis* strain QST 713, and Sonata®, based on the *Bacillus pumilus* strain QST 2808, have both been successfully used in sequential and tank-mix programs with single-site fungicides for the control of black leaf streak, caused by *Mycosphaerella fijiensis*. The main mode of action of Serenade® is based on the production of lipopeptides, and that of Sonata® is based on the production of amino-sugars. Both metabolites have the ability to disrupt or inhibit the development of new cell walls in fungal pathogens such as *M. fijiensis*. These modes of action are different from other fungicides and therefore represent an opportunity for resistance management and synergy with single-site fungicides. In 2010, in the Province of Guayas, Ecuador, a trial was established to demonstrate the efficacy of Sonata® for black leaf streak control. The experimental design was of completely randomized blocks of 4.5 m² with single replicates. Ten plants were marked in each plot and were evaluated according to the parameters of biological pre-warning - which takes into account severity- versus plant-growth stage. The experiment had the following treatments: 1) Sonata® - 1.3 L/ha + adjuvant Ecuafix 2%; 2) Sonata® - 1.0 L/ha + mineral oil – 7 L/ha, and 3) Sonata® - 0.8 L/ha + mineral oil – 7.0 L/ha, alternately mixed with the single site fungicides Difenconazole – 0.4 L/ha, Spiroxamine – 0.5 L/ha, Phyraclostrobin – 0.4 L/ha and Fenpropimorph – 1.0 L/ha, all of them compared with traditional single-site fungicides usually applied in the region. All the treatments with Sonata® reduced the severity of black leaf streak and had higher efficacy than the chemical standards in the last evaluation at 7 days after the last application. Treatments 1 and 2 can be recommended under low disease pressure with shorter application intervals; and treatment 3 under mid to high disease pressures with an application interval of 16 days. Also, in an integrated program in which triazoles, amines, anilinopyrimidines, strobirulins and protective fungicides were compared with/without Serenade®, trials have demonstrated an efficacy equal to Mancozeb as a protectant fungicide. The large-plot trial data were collected over 3 years in Guapiles, Costa Rica, where Serenade® 1.0 L/ha + adjuvant 1% + emulsifier 1%
Efficiency of PCR-Based Diagnostics for the Detection of Banana Streak Viruses in Santa Catarina, Brazil

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Keywords: Musa, phytopathogen, DNA

Banana streak viruses (BSV) are an important pathogen of banana and plantain throughout the world. In Brazil, it has been reported in several states, but only recently it was reported in Santa Catarina. This work aimed to establish a PCR-based methodology for the detection of BSV in banana plants. Three protocols for DNA extraction were tested (DNAzol, Dellaporta and Doyle&Doyle) using leaves from symptomatic (one sample from Luis Alves) and symptomless (two samples from Itajaí) Cavendish (AAA) plants. The presence of episomal or integrated sequences of BSV was verified by using three primer sets: Badna 1A/Badna 4, BSV 4673/BSV 5317 and BSV 5466/BSV 6119. All the protocols produced good quality DNA, verified by the amplification of the Actine housekeeping gene. The primer set Badna 1A/Badna 4 failed to detect BSV in the samples tested under our conditions. The primer sets BSV 4673/BSV 5317 and BSV 5466/BSV 6119 were efficient for BSV detection by generating the predicted amplicons (644 bp and 731 bp, respectively). BSV was detected by the primers BSV 4673/BSV 5317 both in symptomatic and symptomless plants, which has already been shown in the literature. The detection in symptomless plants may be due to the low level of viral expression, not sufficient to cause symptoms but sufficient to be detected by PCR, or due to integrated viral sequences, mostly replication defective, already found in the A and B genomes. PCR analysis not only corroborated results obtained through visual inspection, but also detected BSV on symptomless plants, which is an important finding in terms of early detection and safe germplasm exchange.
Why Sustainable Management of Xanthomonas Wilt in East and Central Africa Has Been Elusive

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Keywords: Banana, management options, resurgence

Banana is an important food and cash crop and constitutes a large proportion of the total crop production in East and Central African (ECA) countries. The average per capita annual consumption of banana in some ECA countries is about 250-300 kg, which is the highest in the world. Banana production has been affected by Xanthomonas wilt caused by a bacteria Xanthomonas campestris pv. musacearum. Besides being a threat to food security in the region, the disease has economic implications, which emanate from yield loss and higher management costs. Without proper management, yields in affected areas can be reduced to almost zero. Disease management approaches include use of cultural practices and awareness creation among the stakeholders along the banana value chain. Such efforts to control the disease were only partially successful and the disease has continued to encroach in previously disease-free areas and to re-emerge in areas where it had been controlled. One of the major challenges to sustainable management of the disease has been stakeholders’ poor understanding of the factors influencing disease spread and severity. Awareness creation among stakeholders has not been sustainable due to limited technical, financial and infrastructural capacity. Incorrect use of cultural management options, such as removal of male buds and lack of appropriate methods for field disinfection of tools, coupled with limited institutional frameworks to enforce existing byelaws and quarantine measures are key drivers to disease endemicity in ECA. It should however be emphasized that no single management option is adequate to sustainably manage the disease. In this paper, we discuss drivers of the disease endemicity, present Xanthomonas wilt management options available to farmers, explore proven options and identify options which have failed to control the disease. Approaches that can help sustainably manage Xanthomonas wilt are suggested.
Comparative Transcriptome Analysis and Genome Assembly of *Fusarium oxysporum* f. sp. *cubense*

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**Keywords:** Panama disease, banana, genomic and transcriptomic analyses

*Fusarium oxysporum* f. sp. *cubense* (Foc), the causal agent of Fusarium wilt of banana, is a highly destructive and genetically diverse pathogen. Despite its economic importance, genomic information of Foc is poor and no transcriptomic analyses have been reported so far. By using 454 sequencing technology, we generated >2.5 million expressed sequenced tags (ESTs) from four Foc strains representing four vegetative compatibility groups (VCGs) and races that infect banana: race 1 (R1, VCG unknown but different from the others here described), race 2 (R2, VCG 0124), subtropical race 4 (SR4, VCG 0120) and tropical race (TR4, VCG 01213). The ESTs were obtained from libraries prepared from mRNA extracted from three physiological states (mycelia, conidia and germinated conidia), which were pooled at a 2:2:1 ratio. Most genes are represented in all libraries, but *in silico* comparative analyses identified a set of unique ESTs for each race (689 for R1, 974 for R2, 296 for SR4 and 555 for TR4), which constitute excellent candidates for diagnostics development, future plant-pathogen interaction studies and functional analyses. In subsequent analyses, a 40x sequencing-coverage (Illumina single reads) of TR4 genomic DNA was assembled in a *de novo* based methodology, resulting in a 29-kb N50 (463 contigs). Preliminary analyses show a high colinearity of EST and genomic data that significantly contributes to the quality of the assembly. Applications of these data will be further discussed.
Calcium Chloride and Magnesium Sulphate in In Vitro Development of Banana Plants

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Keywords: Musa spp., tissue culture, nutrition

Banana cultivation is socio-economically very important in more than 80 countries, especially on small farms. Research related to optimizing micropropagation culture media can improve development of micropropagated plants. Thus, the aim of this study was to evaluate the development in vitro of banana plants submitted to different concentrations of calcium chloride and magnesium sulphate. Stem tips of ‘Prata-Anã’ (AAB) were cultivated in 250 cm$^3$ pots with 50 ml of Murashige and Skoog (MS) culture medium, using a range of concentrations of calcium chloride (0, 220, 440 and 880 mg/L) and magnesium sulphate (0, 185, 370, 740 mg/L). The culture medium pH was fixed at 5.8 ± 0.1 with 1.8 g/L phytage before autoclaving (121ºC, 1 atm, for 20 min). The pots were kept in a growth room with artificial light supplied by daylight special-type fluorescent light bulbs (OSRAM 20 W) with 42 W/m$^2$, mean irradiance, 16-hour light period and 25 ± 2ºC. The experimental design was completely randomized, with a 4x4 factorial arrangement (four concentrations of calcium chloride and four concentrations of magnesium sulphate). Twelve plants were used per treatment, four replications with three plants. After 45 days, number of roots, shoot length (cm) and number of leaves were analysed. Higher number of roots (2.86) and number of leaves (6.0) was observed on MS medium containing 880 mg/L of calcium chloride in the absence of magnesium sulphate. Higher shoot length (5.05 cm) was obtained on MS medium supplemented with 185 mg/L of magnesium sulphate. It can be concluded that the best development in vitro of banana plant ‘Prata-Anã’ cultivar occurs in MS medium supplemented with 880 mg/L of calcium chloride and 185 mg/L of magnesium sulphate.
Anatomical Characteristics of Micropropagated Banana Plants with Different Sources of Silicon

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Keywords: *Musa* spp., structural changes, silicate

Silicon is a chemical element known to promote plant growth and protection by means of alterations in the anatomical characteristics of leaf surfaces. This research was carried out to verify the morphological differences in banana cultivar ‘Maçã’ (AAB) as a result of adding silicon to the medium for *in vitro* cultivation. Banana shoots established *in vitro* were placed on Murashige and Skoog (MS) medium, with 30 g/L sucrose, 1 g/L NAA and solidified with 1.8 g/L Phytagel™. Three sources of silicate were tested, in supplementation to the MS medium: sodium silicate, potassium silicate and calcium silicate, at a concentration of 1 g/L. MS medium without addition of silicate was included as a control. A completely randomized design with four treatments and five replicates was used. After 45 days, anatomical features were evaluated. Increases in both number of stomata and the polar-over-equatorial diameter ratio were obtained using a silicon source in half concentration. Addition of calcium silicate and potassium silicate caused greater concentration of silicon in plantlets, 85% and 81.4%, respectively. The use of silicon in the *in vitro* rooting brings benefits to stomatal anatomy during acclimatization of banana plantlets.

*Sponsors: CNPq/FAPITEC*
Influence of the Parents on the Embryo Rescue of Banana Seeds

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Keywords: Crossing, zygotic embryo, in vitro culture, Musa spp.

The germination of banana seeds is one of several drawbacks in genetic breeding. Besides extreme variability under artificial conditions, germination can be affected by many features, including seed physiological maturity, intensity of disinfection treatment, culture media composition and size, type and morphological aspects of embryos. Seeds from the banana genetic breeding program at Embrapa Cassava & Fruits were studied in order to assess the influence of the parents on the germination rate and the occurrence of abnormalities in embryo structure. Seeds were disinfected in 70% alcohol for 5 min and in 1.25% sodium hypochlorite for 20 min. Excised embryos were classified according to morphological traits and cultured on Murashige and Skoog (MS) salts and vitamins with 3.0% sucrose in the absence of light. Plantlet formation was observed from 7 to 120 days after culture. The average germination rate was 9.4%. From a total of 2580 seeds, 14.2% presented abnormal embryos; 10.9% of the seeds did not present embryos. Most of the cultivated embryos (62.6%) did not regenerate into plantlets. The germination rate for each cultivar was calculated using the ratio between the number of embryos regenerated into plantlets and the total number of embryos cultured from the specific cultivar. From 188 cultivated embryos that had ‘Prata Anã’ (AAB) as female parent, 47 regenerated into plantlets (25%). ‘Prata Pacovan’ and ‘Prata Comum’ female parents presented germination rates of 18.5% (22/119) and 17% (61/359), respectively. These varieties were the ones with the highest germination rates among female parents. The highest germination rates, 65% (26/40) and 22% (3/13) were observed when improved diploids 117100 and 103, respectively, were used as male parents. Combinations between these high-germination-rate parents will be considered for further study.
Growth and Multiplication Ability of *Musa* Genotypes Using the Whole-Corm Technique

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**Keywords:** Cultivar, genotype, ploidy level, substrate

A split-split-plot design experiment was carried out on nine banana genotypes in Malawi [diploids - ‘Kapeni’ (AA), ‘Kambani’ (AB); triploids - ‘Kabuthu’ (AAA), ‘Ngwewo’ (AAB), ‘Saba’ (ABB); and tetraploids - ‘FHIA-02’ (AAAA), ‘SH-3640’ (AAAB), ‘TMBx5295/1’ (AABB), ‘TMBx1378’ (ABBB)] during the winter of 2009 to determine the most suitable developmental stage to obtain corms to optimize the multiplication rate using the whole-corm propagation technique. Three stages were tested: corms obtained from fruiting banana plants, from suckers and from followers. The study also aimed to identify the most suitable substrate between sawdust, sand and loam soil and to establish the multiplication rate of the different banana genotypes. Type of substrate was the main plot factor with genotype and corm age being the sub-plot and sub-sub-plot factor, respectively. The 81 treatments were replicated three times giving a total of 243 plots. Data were collected number of days to regeneration, shoots, roots and leaves, and height and girth of shoots. Genotype and ploidy level had an effect \((P<0.05)\) on the performance, with the triploid cultivars ‘Kabuthu’ and ‘Ngwewo’ showing superiority in all the parameters, followed by tetraploids and diploids. They were the first to produce shoots (6 weeks) and also produced the highest number of roots and leaves after 12 weeks. There was also an inverse relationship between the number of roots and the number of days to regeneration. Corms obtained from fruiting banana plants produced plantlets much faster (48.1 days) and were superior in most aspects compared to corms from suckers and followers. The type of substrate had no significant effect on the performance of the different banana genotypes.
Plant Water Relations, Yield and Quality of Banana in Relation to Differential N and K Fertigation

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Keywords: NK ratios, fertigation, NO₃-N

Field experiments conducted during 2007-09 at the experimental farm of the Indian Institute of Horticultural Research (Latitude 13° 58' N, Longitude 78° 0 E, Altitude 890 m, Av. Rainfall 850 mm), Bangalore, India to study the response of banana cultivar ‘Robusta’ (AAA) to differential nitrogen and potassium application through drip irrigation. The treatments included application of nitrogen and potash (200 N-200 K g/plant/crop) in the ratio of 50N-50K: 75N-25K: 60N-40K: 80N-20K during vegetative stage and these ratios were reversed during reproductive stage, i.e. 50N-50K: 25N-75K: 40N-60K: 20N-80K along with soil application of the recommended dose of fertilizer 200N-108P-200K g/plant/crop. These treatments were replicated four times in a randomised block design. The crop was spaced at 1.5 m between plants and 1.5 m between rows (4444 plants/ha). The main crop yields were higher when N and K were given in the ratios of 50:50 (28.3 kg/pl), 75:25 (28.7 kg/pl) and 60:40 (28.0 kg/pl) during the vegetative and reproductive stages. However, yields decreased when N and K were given in the ratio of 80:20 (25.4 kg/pl). Yields were lowest with soil application of fertilizer (22.0 kg/pl). The yield increase was largely due to a higher number of hands per bunch and higher number of fingers per hand. A similar trend was observed with the first ratoon crop. The total soluble solids were higher with 50:50 NK ratio (21.4°B) followed by 75:25 NK ratio (20.6°B), and again a similar trend was observed in the ratoon crop. The photosynthetic rate was higher with 80:20 NK ratio (13.52 umoles/m2/s) followed by 75:25 NK ratio (12.80 umoles/m2/s), and lower with 60:40 and 50:50 NK ratio. Correspondingly, the transpiration rate was also higher wherever the photosynthetic rates were high. The NO₃-N content increased with soil depth irrespective of the NK ratios and was highest at 30-45 cm soil depth in all the treatments.
Performance of Banana Genotypes of Different Plant Heights under Organic System in Vaza Barris, Brazil

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Keywords: Crop cycle, economy, cultivars, productivity

Banana (Musa spp.) are widely cultivated in different regions of the globe, playing an important role in the main producers’ economies, and providing employment and income for millions of producers. Although several climatic factors constrain banana cultivation, Brazil presents favourable production conditions in most of the country, where in 2009 the cultivated area was around 513,000 ha with an average productivity of 13.7t/ha. The Northeast region contributes around 40.8% of the national total. Wind toppling is one of the biggest problems for banana producers using irrigation. Based on this fact, the objective of the experiment was to evaluate the agronomic performance of five genotypes of banana with different plant heights: ‘PA 4244’ (AAAB), ‘PA 9401’ (AAAB), ‘Maçã Tropical’ (AAAB), ‘Nanicão’ (AAA) and ‘Maravilha’ (AAAB), under an organic system and localized irrigation. The trial was carried out with tissue-cultured seedlings, natural, mineral and organic fertilizers, a microsprinkler irrigation system, and in the absence of soil cultivation or pesticides. The study was carried out in Vaza Barris Perimeter (PIVB), on 1 ha, with 1250 plants. All the cultivars presented good productivity. ‘Nanicão’ displayed the biggest average productivity in both cycles (58.769 kg./ha) followed by ‘Maravilha’ (53.541 kg/ha), ‘PA 9401’ (52.636 kg/ha), ‘Maçã Tropical’ (32.499 kg/ha) and ‘PA 4244’ (30.028 kg/ha). The adoption of this organic production system resulted in high productivity for all the genotypes evaluated, and no wind toppling was observed.
The Benefits of Forage Crops in Establishing a ‘Nanicão’ Banana Plantation

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Keywords: Green manure, cycling of nutrient, biomass

During early plantation establishment, the soil is prone to erosion. To minimize this problem, forage crops may be used for crop management and recycling nutrients in the soil. This study aimed to evaluate dry matter and nutrient content of forage plants grown between recently planted rows of ‘Nanicão’ (AAA) banana plants in Arapongas-PR state. The following treatments were used: black oats (\textit{Avena strigosa} Schreb); wild radish (\textit{Raphanus sativus} L. var. \textit{oleiferus} Metzg.); blue lupin (\textit{Lupinus angustifolius} L.); hairy vetch (\textit{Vicia villosa} Roth); mixture of black oats + wild radish + hairy vetch; spontaneous weeds; spontaneous weeds controlled with post-emergent herbicide (glyphosate 480 g/L) applied after 30 days; and spontaneous weeds controlled by mowing after 47 and 73 days. The experimental design was randomized blocks, with eight treatments and three replicates. At 120 days, a sample of 1 m\textsuperscript{2} was taken of the aerial part of the plant of each plot to determine dry matter and nutrient content of the forage vegetation. At 270 days after the start of the experiment, soil samples were taken in the layer from 0 to 20 cm in all plots. The data were subjected to analysis of variance, and the average compared by Tukey test at 5% probability. Soil analyses showed an increase in organic matter and K content and in base saturation. The largest contributions in dry matter were produced by oats and the mixture. The highest values of recycling N, P and K occurred with green manures. The forage crops provide a portion of the nutrients necessary for the development of the banana plants, mainly N and K, reducing the costs of production.
The Influence of Nitrogen and Organic Matter in Banana Production in the First Cycle of Banana Cultivar ‘Prata Anã’ (AAB)

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Keywords: Musa, fertilization

The 13,700 ha of banana crop to the north of Minas Gerais in Brazil produce about 312,000 tons of fruit, with an average productivity of 22.8 t/ha. This study evaluates the effect of nitrogen fertilization using urea (0, 8, 16 and 24 g N per plant per month) and bovine manure (0, 20, 40, 60 and 80 L per plant per year) (20 treatments in complete factorial design) on the yield of irrigated ‘Prata-Anã’ (AAB). To determine baseline fertility, soil samples were taken during first-cycle flowering at a depth of 0-20 cm. Increases in doses of manure resulted in corresponding linear increases in organic matter content, P, K, Ca, Mg, B and Zn of the soil. Increases in N doses resulted in a quadratic effect on organic matter content, and a linear reduction in P, K and Ca contents. Soil pH was not influenced by the treatments. At harvest of the first cycle, the following characteristics of plant and cycle were not influenced by the treatments: height (2.4 m), pseudostem-diameter basis (20.9 cm), number of living leaves at flowering (16), days between planting and flowering (275), days between flowering and harvest (129), and days between planting and harvest (404). The number of living leaves at harvest increased linearly with the supply of manure. The production characteristics were not influenced by the treatments and presented the following average values: bunches of 13 kg with 9 hands and 138 fruits; central fruit of the external row from the second hand with 16.5 cm of length, 2.9 cm diameter and 100 g weight. The evaluations are still ongoing. During this first trial year, the full influence of upgraded fertility may not have been expressed, and as increases in manure doses improve soil fertility and number of leaves, we expect better yield results in the following cycles.

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**Frequency of Fertigation with Nitrogen and Potassium in Banana Cultivation**

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**Keywords:** Musa, fertigation, nutrient uptake, productivity

Fertigation frequency was evaluated in comparison with manual soil-applied fertilization for the effects of nitrogen and potassium fertilization on growth, development and production of banana cultivar ‘Grande Naine’ (AAA). The experiment was conducted in Ipanguacu city, Assu Valley, Rio Grande do Norte State, in neosol, using a randomized block design with four kinds of fertilization and four fertilization treatments, which were T1: manual soil fertilization; T2: fertigation frequency of 3 on 3 days; T3: fertigation frequency of 6 in 6 days; T4: fertigation frequency of 9 in 9 days. Ammonium sulphate and potassium chloride were used as nutrient sources. The results of the three cycles indicated that there were effects on pseudostem diameter, leaf number per plant, weight of banana tiers, bunch weight and productivity., with treatments T2 and T4 being superior compared with T1 and T3. Further studies are recommended.

**Strategic Amalgamation of Fertigation and Biofertilizer Consortium for Sustainable Production of Banana Cultivar ‘Robusta’ (AAA)**

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Drip irrigation and fertigation technology has revolutionized the efficiency of commercial banana cultivation in recent years. This has helped to increase fertilizer use and reduce NO₃-N pollution of the ground water. It has been clearly demonstrated that fertigation maximizes yields and reduces fertilizer requirements by nearly 25% in banana cultivation. Attempts were made to study the effect of fertigation and biofertilizers on banana cultivar ‘Robusta’ (AAA) during 2009-10 at the Indian Institute of Horticultural Research, Bangalore, India, situated at 13°58’N and 78°E at an altitude of 890 m. Three levels of fertigation - 100% of Recommended Doses of Fertilizer...
(RDF) (200 N, 110 P, 200 K g.plant\(^{-1}\).crop\(^{-1}\)), 75% RDF (150 N, 82.5 P, 150 K g.plant\(^{-1}\).crop\(^{-1}\)) and 50% RDF (100 N, 55 P, 100 K g.plant\(^{-1}\).crop\(^{-1}\)) - and three levels (100, 200, 300 g.plant\(^{-1}\).crop\(^{-1}\)) of biofertilizer consortium (Azospirillum, phosphorous-solubilizing bacteria and arbuscular mycorrhizal fungi - AMF) were combined with the soil-applied RDF. These treatments were laid out in a randomised block design with three replicates. Fertigation with 100% RDF and 300 g of consortium produced significantly higher yields (115.23 MT/ha) than other treatments. The yield increase was nearly 48% as compared to soil application of fertilizers (77.7 MT/ha). However, the yield difference between 100% and 75% RDF with biofertilizer consortium was not significant. There was no significant yield difference between 75% (110.47 MT/ha) and 50% (95.54 MT/ha) RDF. The yield reduction was around 12% at 50% RDF as compared to 75% RDF. The soil samples taken after 6 months at three different depths indicated that the soil quality in terms of microbial population was higher in the treatments which received 75% RDF along with 300 g of biofertilizer consortium, with soil respiration 9.31 C mg.kg\(^{-1}\).soil.h\(^{-1}\), AMF root colonization 68.2%, spore load 13.20 number.g\(^{-1}\)dry-soil, rhizosphere colonization of Azospirillum 3.5 x 10\(^6\) cfu/g soil, phosphorous solubilizing microbes 6.7x 10\(^6\) cfu/g dry-soil, dehydrogenase activity 98.6 µ of TPF released.g\(^{-1}\).soil.h\(^{-1}\), microbial biomass carbon 97.2 mg C/kg soil and retention of applied bio-inoculants. These values were higher as compared to the initial microbial population of the soil.

**Soil Chemical Attributes under Organic Management in Banana Crops**

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**Keywords**: Green manure, *Canavalia ensiformis*, *Arachis pintoi*

Banana is a demanding crop for nutrients, especially potassium (K) and nitrogen (N). In an organic system, nutrients are provided from natural sources such as green manures (leguminous and non-leguminous crops). The improvement of soil chemical attributes is important for organic banana production sustainability. The objective of this work was to evaluate chemical attributes (K, Ca, Mg, organic matter–OM and basis saturation–V%) of soil with six banana genotypes grown under organic management. Three cycles
were monitored using soil samples collected in the final stage of each fruiting cycle, with three replicates, at 40 cm from the plant and 0-20 cm and 20-40 cm deep, from banana plants grown with jack bean (*Canavalia ensiformis*) cover (cut during the dry season) and perennial forage peanut (*Arachis pintoi*). For nutrients supply, natural phosphate was applied at planting, and organic compost, castor bean cake and wood ash were used routinely on the plots. The attributes evaluated were compared between the vegetal covers and with the initial value (before planting). Potassium (K), the most absorbed nutrient by bananas, increased 7-158% in comparison to its initial value in the soil, notably for the *Arachis pintoi* cover (13% to 158%), at 20-40 cm (75% to 158%) and after the second cycle. The increase in Ca content was more evident also at the end of the second cycle, reaching 4.85 cmol$_c$/dm$^3$ at 0-20 cm with *Arachis pintoi* and 2.13 cmol$_c$/dm$^3$ at 20-40 cm with *Canavalia ensiformis*; with 94% and 64% increment, respectively. The increase in Mg content in the soil reached 593% at 0-20 cm (2.08 cmol$_c$/dm$^3$), after the second cycle. The increase in the OM in the soil varied from 108% (15.65 g/kg) at 0-20 cm to 138% (12.42 g/kg) at 20-40 cm, both for the *Canavalia ensiformis* cover. The V value also increased reaching 78-92%, being higher after the third cycle and higher than the recommended value for bananas (70%). Thus, in general, the *Arachis pintoi* cover promoted higher values for the attributes evaluated, notably at top (0-20 cm) layer and after the second fruiting cycle.

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**Soil Microbiological Attributes under Organic Management in Banana Crops**

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**Keywords:** Microbial biomass, phosphatase activity, metabolic coefficient

Banana produces high biomass, with approximately 66% of the vegetative mass being returned to the soil as pseudostem, rhizomes and leaves, representing 10 to 15 t.ha$^{-1}$.year$^{-1}$ of dry matter. However, these quantities differ between varieties and management practices used. The resulting mulch is important for soil protection, increasing soil water retention and its exchangeable bases (K + Ca + Mg), influencing biological attributes and consequently crop yield. Impact on microbiota was evaluated in soil samples,
with three replicates, collected at 40 cm from the plant and at 5-10 cm deep in the following cultivars: ‘Prata-Anã’ (AAB), ‘Caipira’ (AAA), ‘Thap Maeo’ (AAB), ‘Maravilha’ (AAAB), ‘Pacovan Ken’ (AAAB) and ‘Tropical’ (AAAB), under organic management. The microbiota evaluations were: a) carbon (C) of the microbial biomass (MB-C); b) C of CO$_2$ released during basal respiration; c) acid phosphatase activity; and d) the metabolic coefficient in the soil ($q$CO$_2$). Nutrients were supplied as follows: natural phosphate applied at planting, and green manures (Canavalia ensiformis and Arachis pintoi), organic compost, castor bean cake and wood ash used routinely on the plots. Microbiological attributes evaluated were compared between cultivars and with the reference value (without vegetation). The soil under ‘Maravilha’ presented a MB-C (183.7 mg/kg) that was 13.6% higher than the reference sample. Except in the soils with ‘Tropical’ and ‘Prata-Anã’, cropping with the remaining cultivars promoted an MB-C higher than the reference. Only soil from the ‘Thap Maeo’ replicates displayed a C release (as CO$_2$, 21.1 µg.g$^{-1}$.day$^{-1}$) higher than the reference (14.5 µg.g$^{-1}$.day$^{-1}$), indicating greater microbial activity and organic matter degradation. All cultivars promoted acid phosphatase activity greater than the reference value (248.3 µmol.g$^{-1}$.h$^{-1}$), varying from 4% to 53%, maybe due to the greater amount of biomass in banana crops and the organic management adopted, which favours microbial activity and detection of this enzyme. For $q$CO$_2$, the values for the soil with ‘Thap Maeo’, ‘Maravilha’ and ‘Prata-Anã’ were 46%, 29% and 5%, respectively, higher than the reference value (3.74 µg CO$_2$/µg C/h x 10$^{-3}$), indicating greater microbiota metabolic efficiency, notably in the soil cultivated with ‘Thap Maeo’. The use of banana biomass for mulching influences soil biological attributes and it is important for sustainability of organic banana production.

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**Comparative Study on the Performance of ‘FHIA-03’ (AAAB) in Home Gardens and on Farms in Ghana**

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Plantains are essential crops for many countries in Africa. A comparative study was conducted on the performance of a tetraploid hybrid cooking banana (‘FHIA-03’) in home gardens with high soil water retention and farms. Trials were conducted at three locations and over three crop cycles. Plant density was 1667 plants/ha. No soil amendment was added. Data were collected on
agronomic and yield characteristics. The results showed that there was a significant difference ($P > 0.05$) between the numbers of leaves at flowering in home gardens and farms and also across locations. There was over 60% increase in number of leaves in home gardens over farms. There was a significant difference in the circumference of the pseudostem between home gardens and on farms. Pseudostems were over 65% bigger in home gardens compared to those in farms and over crop cycles. There was a continuous increase of about 20% in pseudostem girth from plant crops to the second ratoon. There was significant difference in the plant height between the home gardens and on the field, with the plants in the home gardens being taller compared to plants in the farms. The yield was significantly higher in home gardens than in the farms. There was a significant increase in yield across crop cycles. Number of hands and fingers were significantly higher in home gardens compared to those in the farms. The finger sizes were also bigger in the home gardens compared to farms. The hybrid was very susceptible to black leaf streak disease in the farms while their leaves were completely clean in the home gardens. The results indicate that the continuous dumping of organic matter in the home gardens has contributed to the significant differences observed in the agronomic characteristics and yield of the hybrid in the home gardens compared to the farms. The continuous increase in yield and pseudostem girth could also be attributed the increase in soil organic matter levels which has led to increased soil water retention.

**Growth and Yield of Banana Cultivar ‘Galil 18’ under Four Water Levels and Potassium Doses in a Clay Soil of Coast Tableland**

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**Keywords:** Dry mass, potassium, nitrate, fertigation

Banana crops demand high nutrient levels that usually are supplied by conventional fertilization or by irrigation water. Cultivar ‘Galil 18’ is little-studied, lacking information related to growth and yield variables. This work aimed to evaluate vegetative growth, yield variables and K and N accumulation.
in the aerial parts of ‘Galil 18’ under four irrigation levels and four dose rates of potassium in Reconcavo, Bahia State. The work was carried out in the experimental fields of Embrapa Cassava & Fruits located at Cruz das Almas, BA. The experiment followed a random block design, in a factorial scheme 4x4 with three replicates. Irrigation water levels were based upon 30, 60, 90 and 120% of ETo. The potassium doses were 0, 400, 800, 1200 kg/ha. Vegetative growth, production variables and the uptake of K and N by the several organs of aerial part of plants were all evaluated. Potassium dose rates did not influence significantly the growth and production variables. The pseudostem was the largest depository of K (50%), while the leaves were responsible for accumulating the largest amount of N (71.5%). The exportation of K and N by the bunches represented 25% and 15% respectively, of the total uptake by ‘Galil 18’.

**Yield of Two Banana Pome Subgroup Genotypes under Different Irrigation Systems**

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**Keywords**: Production, genotypes AAB and AAAB, water distribution

Banana plants grown under different irrigation systems might differ in productivity even under the same crop conditions. This might result from changes in root distribution, diffusive flux of nutrients in the soil and in plants, with consequent changes in plant physiology, as well as the variability between genotypes. This study aimed to evaluate the yield characteristics of two banana genotypes of the Pome subgroup under different irrigation systems in semi-arid conditions. An experimental design in randomized blocks was adopted, with six treatments in a factorial scheme (3x2): three irrigation systems (conventional sprinkler, microsprinkler and drip); and two genotypes [‘Prata-Anã’ (AAB) and ‘PA42 44’ (AAAB)]. Four replications were used, with six plants per plot. Yield characteristics, including weight of bunch, hands and stalk, average weight of hands, weight of the top five individual hands, number of hands per bunch, number of fruits per bunch, number of fingers per hand, weight, length, diameter and curvature index of the fruit, were evaluated at harvest time. Significant interaction was found only for the weight of the fifth hand and number of hands per bunch in the first cycle; also, weight of the second, fourth and fifth hand and average weight of hands showed significant interactions in
the second production cycle. The weight of the bunch in the second cycle and the number of hands in the third cycle was higher for plants grown under the sprayer and sprinkler systems compared to drip irrigation. The means of total bunch weights and first hand weights were higher for sprayer than those obtained under drip irrigation during the second cycle. ‘Prata-Anã’ had a higher number of fruits and hands per bunch, and ‘PA42-44’ hybrid had greater weight, length and fruit diameter.

Root Distribution of Banana Cultivar ‘Prata Gorutuba’ Irrigated by Different Trickle Systems

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Keywords: Musa, root length density, trickle irrigation

Banana is an important crop in Brazil, not only due to the large market but also to the large number of jobs created by this agribusiness. The objective of the work was to evaluate banana root distribution under different configurations of trickle irrigation systems. The experiment was carried out at the Experimental Station of Gorutuba, Nova Porteirinha, Minas Gerais State. The experimental design followed a random block with five treatments and five replicates. Treatments consisted of three systems of microsprinklers with emitters of flow rates 35, 53 and 70 L/h and two drip systems, with one lateral line per plant row and with two laterals per plant row. Root sampling was made by using an appropriate auger for three plants by treatment. Samples were collected at distances of 0.25; 0.50; 0.75 and 1.00 m from the plant and at 5 soil depths (0.10; 0.20; 0.40; 0.60 and 0.80 m). The variance analyses showed difference among root length densities (RLD) at evaluated depths. The largest RLDs were found at 0.20 m depth. There was no statistical difference among RLDs for the evaluated distances from plant and for the irrigation systems. The effective root depth with 80% of total roots of the profile was found at 0.40 m depth.
Stomatal Conductance of Commercial Banana Cultivars Submitted to Water Stress

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Keywords: Drought tolerance, physiological parameters, stomatal resistance, Musa

Among the many limiting factors in plant production, water deficit is highlighted for adversely affecting basic water relations in plants. The objective of this work was to study response differences of 26 banana genotypes with regard to stomatal resistance and leaf temperature during a period of stress by continuous drying of the soil. Plants were submitted to water stress by suspending irrigation during a period of 16 days, subdivided into four periods to better analyze the data. The first period was with irrigation, and the second, third and fourth periods without irrigation. Daily readings were carried out between 1:30 and 3:00 pm using a porometer (AP4-Delta). The experimental design was in completely randomized blocks with three plants submitted to water stress and two control plants. ANOVA and the Tukey test at 5% probability were used. Water stress was most severe in the fourth period, and the following genotypes presented good results for stomatal resistance values: ‘JV 42-135’ with 136.66 m/s, ‘Calypso’; ‘YB 42-47’ with 126.39 m/s; ‘Japira’ with 123.14 m/s and ‘Maravilha’ with 112.33 m/s. The increase in stomatal resistance may infer that these banana genotypes may be more tolerant to drought conditions whereas the others are more susceptible.
Characterization of Banana Cultivar ‘PA 42-44’ Fruits under Regulated Irrigation Deficit in the North of Minas, Brazil

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Keywords: Musa, post harvest, irrigation scheduling

The use of a suitable irrigation schedule that allows optimal banana growth and fruit quality along with increased water use efficiency is important for waste water reduction. The objective of this work was to evaluate the post-harvest quality of banana cultivar ‘PA 42-44’ fruits under reductions of irrigation water in specific growth phases (regulated irrigation). The field experiment and post-harvest evaluations were carried at Gorutuba Experimental Farm, Epamig, Nova Porteirinha city. The design was random block with seven treatments (levels of water reduction during specific growth phases) and five replicates. The following physical and chemical fruit quality variables were evaluated: dropping resistance, pulp strength, fruit length, fruit diameter, pulp/peel ratio, total soluble solids, titratable acidity and pH. Fruits from plots with total irrigation at phases I and II and 55% ETc at phase III, and with total irrigation at phases I and III and 70% ETc at phase II showed higher dropping resistance, pulp strength and total soluble solids. Fruits from plots with total irrigation at phases I and II and 70% ETc at phase III showed lower dropping resistance and total soluble solids. Larger fruit length and fruit diameter was obtained at total irrigation plots, but the ratio pulp/peel was smaller in this treatment. Fruits harvested with total irrigation at phases I and II and 85% ETc at phase III were larger. Titratable acidity of fruits from plots with total irrigation at phases I and II and 55% ETc at phase III was statistically higher.
Influence of Application of Different Water Levels on the Productivity of Banana Cultivar ‘Grande Naine’

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**Keywords:** Irrigation of banana, productivity, irrigation management

The study aimed to evaluate the influence of different water levels on yields of banana cultivar ‘Grand Naine (AAA) in the 1st production cycle. The experiment was conducted at EMBRAPA/CNPMF, spaced 2 x 2.5 m. A drip-irrigation was system used with four emitters per plant, with a flow rate of 4 L/hour. The experimental design was randomized block with six water levels and eight replicates. Treatment L1 corresponded to rain during the study period and the other treatments corresponded to rain + irrigation. The water level of the L6 treatment was calculated based on the values of Kc (crop coefficient) of culture and reference evapotranspiration (ETo). The blades applied to other treatments were calculated based on leaf area AF (m²) and ETo basis for the calculation of crop evapotranspiration: \( L = ETo \times AF \times K \), where K is the transpiration coefficient ranging between 0 in L1 treatment, 0.18 in L2, 0.37 in L3, 0.56 in L4 and 0.74 in L5. Analysis of variance showed a significant effect of water levels on stalk weight, number of hands per bunch, weight of bunches, number of fruits per bunch, fruit length and overall productivity. The average diameter of the fruit was not affected by water levels. Treatments L4, L5 and L6 were statistically equal and superior to the other treatments for the following variables: number of hands per bunch, bunch weight without stems, number of fruits per bunch, fruit length and yield. L1, which received the least amount of water, was statistically equal to all other treatments only in fruit diameter. The amount of water that provided the highest yield was estimated at 1416 mm/cycle, but the comparison of means by Tukey test \((P <0.05)\) showed that the adopted management for L4, L5 and L6 were statistically the same for most production variables. Water use efficiency (production.ha\(^{-1}\).mm\(^{-1}\) water applied) of L2 (0.026), L3 (0.0257), L4 (0.0277), L5 (0.0286) and L6 (0.0295) were statistically the same over L1 (0.0124 kg. ha\(^{-1}\).mm\(^{-1}\)). Therefore it is recommended to use the irrigation management treatments of L4, L5 and L6, to obtain the best yield.
Agronomic Evaluation of Prata Anã Banana Genotypes in Brazil’s Cerrados

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Keywords: Field evaluation, fruits yield, Sigatoka, Musa

Commercial banana cultivation in the Cerrados depends on the selection of genotypes that are well-adapted to local growth conditions, disease resistant and have high yield potential. The favourable climate and soil in the Cerrados provide a context in which banana can be successfully grown, besides promoting increased commercial demand. However, research on banana genotype selection for cultivation in the Cerrados is still scarce. Embrapa’s Banana Genetic Breeding Programme is testing six ‘Prata Anã’ genotypes (‘FHIA-18’, ‘Garantida’, ‘Maravilha’, ‘PA42-44’, ‘PA94-01’ and ‘Prata Anã’ as the control) at Embrapa Cerrados (Planaltina-DF, Brazil) for yield and disease resistance over three consecutive harvests from 2008 to 2011. Seedlings were transplanted in January 2008, following a randomized complete block design with three replicates of six plants each, spaced at 3 x 2.5 m. Each plant received 60 g of P₂O₅ and 15 L of cow manure at planting, and 45 g of N and 45 g of K₂O every 45 days. Plots were hand-weeded twice, besides intercropping with beans and taro. Irrigation was done by a microsprinkler system (4 to 6 mm per day). The time from planting to 3rd bunch harvest varied from 931 (‘FHIA 18’) to 1135 (‘Maravilha’) days. Average yields for 1st, 2nd and 3rd harvests observed for each genotype were as follows: ‘Prata Anã’ (20.5; 37.5 and 25.8 t/ha); ‘FHIA 18’ (14.6; 40.7 and 32.9 t/ha); ‘Garantida’ (21.0; 34.7 and 29.3 t/ha); ‘Maravilha’ (36.9; 57.7 and 41.0 t/ha); ‘PA 42-44’ (20.0; 38.8 and 33.8 t/ha); and ‘PA 94-01’ (31.0; 25.5 and 35.8 t/ha). ‘Maravilha’ had the highest average and accumulated yields (45.2 and 135.6 t/ha), while ‘Prata Anã’ yielded 27.9 and 83.8 t/ha, respectively. The genotypes ‘Garantida’ and ‘PA42-44’ had the lowest Sigatoka leaf spot severity averages, while ‘Maravilha’ and ‘Prata Anã’ had the highest.
Agronomic Evaluation of Cavendish Banana Genotypes in Brazil’s Cerrados

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Keywords: Breeding, fruits yield, Sigatoka

Cavendish-type bananas are among the most popular worldwide. The Brazilian Cerrados presents a favourable climate with well-defined seasons (dry from April to October and rainy from November to March), adequate water availability for irrigation and favourable soils, in which bananas can be successfully grown and which stimulate commercial demand. However, research on Cavendish-type bananas in the Cerrados is still poor. Embrapa’s Banana Genetic Breeding Programme tested four Cavendish genotypes (‘Bucanero’, ‘FHIA-02’, ‘FHIA-17’ and ‘Grand Naine’ as the control) at Embrapa Cerrados (Planaltina-DF, Brazil) for disease resistance, yield and agronomic performance over three consecutive harvests from 2008 to 2011. Soil (clay = 340 g/dm³) was limed to achieve 60% base saturation. Seedlings were transplanted in January 2008, spaced at 3 x 2.5 m (1333 plants/ha) following a randomized complete block design with three replicates of six plants. Each plant received 60 g of P₂O₅ and 15 L of cow manure at planting, and 45 g of N and 45 g of K₂O every 45 days. Plots were hand-weeded twice, besides intercropping with beans and taro. Irrigation was done by a microsprinkler system (4 to 6 mm per day). The time from planting to 3rd bunch harvest varied from 921 (‘FHIA-02’) to 1032 (‘Grand Naine’) days. Average yields for 1st, 2nd and 3rd harvests observed for each genotype were as follows: ‘FHIA-02’ (21.3; 25.3 and 35.9 t/ha); ‘Grand Naine’ (46.7; 31.4 and 38.4 t/ha); ‘Bucanero’ (32.8; 58.4 and 47.8 t/ha); and ‘FHIA 17’ (43.7; 56.7 and 48.2 t/ha). ‘FHIA-17’ had the highest average and accumulated yields (49.5 and 148.6 t/ha), while ‘Grand Naine’ yielded 38.8 and 116.5 t/ha, respectively. The genotype ‘Bucanero’ had the lowest Sigatoka leaf spot severity average, while ‘Grand Naine’ and ‘FHIA-17’ had the highest.
Productive Performance of Banana Genotypes on the Coastal Tablelands, Sergipe, Brazil - First Cycle

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Keywords: Musa spp., genotypes, genetic breeding

The main strategy for banana disease control is the development of new productive and resistant cultivars. The aim of this work was to evaluate banana genotypes under the environmental conditions prevailing in the coastal tablelands, in order to select materials with better commercial and agronomic traits at the end of the first production cycle. The work was implemented at the experimental field station of the Embrapa Coastal Tablelands, at Nossa Senhora das Dores, Sergipe, Brazil. The experiment was conducted in a randomized block design with 22 treatments and three replicates; each plot was formed by six plants, and each useful plot for four plants. The variance analysis was done by Scott-Knott test at a 5% significance level. The genotypes were grouped into two groups according to leaf number at harvest: group 1 with 6.41 to 4.81 leaves (‘YB 42-17’ and ‘Grand Naine’) and group 2 with 4.41 to 3.63 leaves (‘PA 94-01’ to ‘Caipira’). ‘FHIA-2’3 showed a higher bunch weight of 27.33 kg followed by ‘Bucaneiro’ (23.5 kg), ‘PV 79-34’ (22.38 kg), ‘Maravilha’ (20.17 kg), ‘Thap Maeo’ (19.54 kg), ‘PA 94-01’ (19.08 kg) and ‘Grand Naine’ (18.45 kg). The same genotypes performance was observed for total and average weight of the hands (tiers). The number of hands ranged from 11.11 (‘FHIA-23’) to 5.92 (‘Japira’). The highest number of fruits per bunch was found for ‘FHIA-23’ (182.33) and ‘Thap Maeo’ (161.07), and the smallest for ‘Pacovan’ (68.30). The number of fruits per hand ranged from 16.33 (‘FHIA-23’) to 11.23 (‘Pacovan’). The highest value observed for fruit weight was 267.67 g for ‘Prata-Anã’ and 215.75 g for ‘Maravilha’. Three clusters were formed, when earliness was evaluated: ‘FHIA-23’ (632.11 days), ‘Garantida’ (626.36 days) and ‘Tropical’ (625.30 days) were classified as ‘late’; ‘Bucaneiro’, ‘Maçã’ and ‘Pacovan Ken’ were ‘intermediate’, and the others were ‘early’.

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Field Performance of Banana Genotypes in the Subtropical Climate of Brazil

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Keywords: Agroecology, cultivar, organic bananas

A field trial using 23 banana genotypes was conducted on the southern coast of Santa Catarina State, Brazil, in a small banana farm, where a subtropical (Cfa) climate prevails: warm in summer and cool in winter. The average annual temperature is 19°C, ranging from 14°C in July to 24°C in February, with an average annual rainfall of 1400mm-1600mm, well distributed throughout the year. Frosts and strong winds are the main climate constraints for banana in the region, while Sigatoka leaf spot (caused by Mycosphaerella musicola Leach) and Fusarium wilt (caused by Fusarium oxysporum f. sp. cubense) are the main fungal diseases. The banana plantlets were produced by Embrapa/CNPMFT, Cruz das Almas, Bahia, being part of the banana breeding program that has been testing new materials nationwide. Most of the genotypes presented resistance to Sigatoka leaf spot, which is an advantage to organic farming. However, some of the genotypes were susceptible to Fusarium wilt. Many genotypes presented tall pseudostems, making them susceptible to wind toppling following the incursion of cold fronts in the region. The average weight of the first bunches ranged from 6.4 kg to 26.3 kg for ‘Dwarf Prata’ and ‘FHIA-17’, respectively. The results are important to identify banana genotypes adapted to small farming in subtropical conditions.

Production of ‘Nanicão’ Banana (Musa, AAA) in Subtropical Climate Cwa

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Keywords: Musa, seasonality, yield

The subtropical climate classified as ‘Cwa’ is not ideal for banana production, because of the typical dry winter with low temperatures which
constrain plant development. This research studies how a Cwa climate influences production of cultivar ‘Nanicão’ (AAA, Cavendish group). The experiment was conducted in a three-year old banana plantation, in Tiête, São Paulo city. The total area was 16 ha containing plants produced from micropropagated seedlings, with a spacing of 2.4 x 2.0 m, irrigated by sprinkling. Meteorological data was offered by the Integrated Centre of Agro-meteorological Information. The banana trial was divided in four parts, each containing 2000 ‘Nanicão’ plants, and was evaluated between January 2009 and March 2011. Banana yields oscillated widely during the production cycle. The highest yields occurred in the cold and dry period (April to September), averaging 3.850 t/ha in 2009 and 4.998 t/ha in 2010. Bunches harvested in this period had the largest mass because of the high temperature and abundant water availability during the vegetative period and initial flowering. By contrast, significant yield decreases occurred in the warm and high humidity period (October to March). The yield averages in this period were 3.4 t/ha in 2009/2010 and 1.428 t/ha in 2010/2011. The low yields in this period were due to low temperatures and dry conditions during the vegetative period and initial flowering.

Production Cycle of ‘Nanicão’ Banana (Musa, AAA) in Subtropical Climate Cwa

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Keywords: Musa, climatic variation, harvest

This work intended evaluate the crop cycle of banana cultivar ‘Nanicão’ (AAA, Cavendish group) in climate Cwa which is characterized by dry and low temperature in the winter. The experiment was conducted between September 2005 and December 2010, in Tiête, São Paulo city. Planting occurred in September 2005 with 1110 micropropagated seedlings. Four crop cycles were evaluated: the ‘vegetative cycle’ (crop plant), determined as the period from planting seedlings to bunch harvest (more than 50% of bunches); the subsequent three cycles were termed production cycles: the first production cycle was the interval connecting the harvest of crop plant to harvest of ratoon 1, in this manner successively were determined the second (ratoon 2) and third (ratoon 3) production cycles. The duration of harvest periods (harvest of first bunch to last one) of each cycle were also calculated, and an analysis of temperature influences was done. The results showed that in this climate, the duration of 2\textsuperscript{nd} and 3\textsuperscript{rd}
production cycle of ‘Nanicão’ increased more than expected, in both production cycles the harvest period was extended by 16 months. The harvest period of the vegetative cycle (crop plant) and first production cycle on the other hand were as expected compared with other regions (i.e. 3.5 and 6 months respectively). This high increase of the harvest period of 2\textsuperscript{nd} and 3\textsuperscript{rd} production cycles were caused mostly by climate conditions of this region. The cooler temperature experienced between May and August, with medium temperature of 18°C, may delay plant development by the fewer growing-degrees-days (GDD) accumulated at this time of year. The knowledge of duration of the first cycles and the determining factors is important, because it enables predicting the time of first harvest and developing and implementing appropriate product marketing strategies.

**Correlation between the Morphological Characters and Bunch Weight of Banana Cultivar ‘Tropical’**

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**Keywords**: Production, prediction, regression model

The study evaluates the relationship of traits measured at flowering and harvest in relation to bunch weight in bananas. The experiment consisted of a uniformity trial, conducted in Guanambi, BA, with cultivar ‘Tropical’ (YB42-21, AAAB hybrid), totalling 360 plants in an area of 2160 m\textsuperscript{2}. We assessed the vegetative characters (plant height, pseudostem circumference, number of suckers issued and number of green leaves at flowering and harvest) and the characters of yield (bunch weight, number of hands and fruits, weight of the second hand, and fruit length and diameter), all over two growing seasons. In the evaluation, each plant was considered as a basic unit, in an area of 6 m\textsuperscript{2}, totalling 360 basic units. Multiple linear regression was used to estimate bunch weight, where the most significant variables included number of living leaves, number of fruits per bunch, weight of the fruit, length of the fruit (cm), weight of the rachis (g) and length of the stalk (cm); with the following prediction equation: \( PCA = -5.249 + 0.11NLL + 0.066NFB + 0.046FW + 0.183LOF + 2.039RW - 0.011LS \). The coefficient of determination of MLR was 71\%, meaning that the independent variables explained 71\% of the total variation in bunch weight.
Study of the Correlations between Banana Characteristics Evaluated in Two Production Cycles

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Keywords: Production, prediction, yield, Musa

The association between banana characteristics, fundamental to estimate bunch production, can be evaluated through phenotypic, genetic and environmental correlations. The knowledge of these relationships is very important for the researcher in choosing the most efficient method to be used in breeding programs. The objective of the present work was to evaluate the main correlations between the characteristics of the banana plant in two production cycles. The experiment was carried out at Guanambi, BA, with ‘Tropical’ (YB 42-21, AAAB hybrid), planted at 3 x 2 m spacing, in 11 rows with 52 plants each and 9 rows with 40 plants per row considered as useful, with a total of 360 plants in an area of 2160 m². The following characteristics were considered: plant height, pseudostem perimeter, number of living leaves during flowering, number of suckers during harvest, number of living leaves at harvest, bunch weight, rachis weight, hand weight, stalk length, stalk diameter, number of hands, number of fruits, weight of second hand, average weight of fruit, external length of fruit and lateral diameter of fruit. The associations between the characteristics throughout both cycles were mainly positive and significant at 1%. Average correlation was observed between bunch weight and weight of the second hand in the first cycle (0.73**) and second cycle (0.66**), indicating that the weight of the second hand can be used to predict the total weight of the bunch.
Comparison of Techniques for Predicting Bunch Yield of Banana Cultivar ‘Tropical’: Neural Networks vs. Multiple Linear Regression

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Keywords: Computational intelligence, production, Musa

Usually, the decision processes in agriculture require the use of response models to evaluate the profitability of the crop. This study investigated the potential of using the culture’s characteristics in predicting production responses by applying two techniques: artificial neural networks (ANNs) and multiple linear regression (MLR) in plants of banana cultivar ‘Tropical’ (YB 42-21, AAAB hybrid). The experiment was a test for uniformity, conducted in Guanambi, Bahia, with a total of 360 plants, planted in a 3 x 2 m spacing over an area of 2160 m². The characteristics evaluated over two cycles of fruit production were: yield, bunch weight, number and length of bunches and fruits, diameter of the fruit, and number of living leaves at harvest. In the evaluations, each plant was considered as a basic unit (bu) occupying an area of 6 m²; therefore, 360 basic units (bu) were studied. According to the analyses, the neural network proved to be more accurate in forecasting the weight of the bunch in comparison to the multiple linear regressions in terms of the mean prediction error (MPE), mean square deviation (MSD) and coefficient of determination (R²).
Evaluation of the Coefficient of Variation in Banana Experiments

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Keywords: Variables, experimentation

The objective of the present work was to suggest a classification for coefficients of variation (CV) in regard to the most used variables in banana experiments. The following characteristics were evaluated: plant height, pseudostem diameter, bunch weight, hand weight, fruit weight, number of fruits per bunch, fruit length, fruit diameter, number of hands and number of days from planting until harvest. For the classification of the CV, initially the average, standard deviation and variance of the CVs were calculated for each variable mentioned earlier. The CVs were classified according to the averages (x) and the standard deviation (s) as proposed by Garcia: low (CV ≤ x – s); average (x – s < CV ≤ x + s); high (x + s < CV ≤ x + 2s); very high (CV > x + 2s). After data clustering, the Lilliefors normality test was carried out showing that all the variables presented normal distribution. The ranges of classification of the CV for the banana experiments presented specific characteristics for each variable evaluated. Bunch and hand weight presented the highest CV values, whereas the lowest were presented by the fruit diameter and number of days from planting until harvest.
Evaluation of Banana Hybrids in Malawi

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Keywords: FHIA hybrids, BBTV, cooking banana, cultivars

Trials were conducted at Limphasa, Bvumbwe, Kasinthula and Mulanje to evaluate the agronomic performance and quality of eight introduced FHIA and other banana hybrids. Data were recorded on growth and yield parameters and organoleptic features. In addition, disease incidence (%) was also collected at Limphasa in order to assess the introduced cultivars against Banana bunchy top virus (BBTV). Results showed that ‘FHIA-17’ (AAAA) and ‘FHIA-25’ (AAAB) performed better in all variables both on station and on farm. The yield of ‘FHIA-17’ (46.8 kg/bunch) and ‘FHIA-25’ (50.7 kg/bunch) was significantly higher ($P < 0.001$) than the control ‘Williams’ (21 kg/bunch). Preference tests revealed that 18 out of 47 people (38%) liked ‘FHIA-17’ while only 15 (31%) liked ‘Williams’. ‘FHIA-25’ was less preferred (only 6% liked this hybrid), mainly because of its unattractive peel colour and softness of the pulp. With regards to shelf life, ‘FHIA-17’ stored longer (8 days after ripening) followed by ‘FHIA-23’ (AAAA), ‘SH-3640’ (AAAB) and ‘Williams’ which remained firm and attractive up to 7 days from the date of ripening. ‘FHIA-25’ showed poor storage characteristics, being only able to keep well for 3 days after ripening. All the test genotypes were susceptible to BBTV, with the cooking types showing some degree of tolerance.

Determinants of Plantain Producers’ Technical Efficiency in Cameroon

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Keywords: Musa, translog, production function

In order to analyze the technical efficiency of banana and plantain producers in Cameroon, a translog production function of a sample of 86
161 producers from three regions with different agro-ecological and demographic factors (the South, the Southwest and Littoral) was taken. The results show that the technical production factors, such as the farm area and the combined effect of using improved plants and chemicals, contribute positively to plantain production in Cameroon. However, investment factors such as transportation and watering of plants do not have a significant effect on production. Furthermore, environmental characteristics of the farming area, such as high population density, have a negative effect on the technical efficiency of plantain production in Cameroon, a finding that may not be true in other plantain-growing areas. Socioeconomic characteristics of farmers, such as ethnic group and the completion of primary and secondary education, improve banana and plantain production in Cameroon while increasing age of farmers has a negative effect on production.

**Physiological and Biochemical Effects of Banana Leaf Tissue Injury**

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**Keywords:** Injury, polyamines, peroxidase, polyphenol oxidase, lipoxygenase

Injury caused to banana leaf tissue by different agents and in different ways was investigated with respect to total polyamines levels and to some enzyme activities. Polyamines, putrescine, spermidine and spermine have shown to be involved in a variety of plant growth, defense system and developmental processes, including cell division, vascular differentiation, root initiation, shoot formation and flower initiation. Plant defense systems could be induced by microbial products in incompatible (failure to result in disease), in compatible (resulting in disease), and plant-microbe interactions. Therefore, the levels of total polyamines and specific polyamines (agmatine, nor-spermidine, spermine, spermidine and putrescine) were quantified. The profiles presented by the peroxidase, polyphenol oxidase and lipoxygenase were evaluated. Cultures of *Mycosphaerella fijiensis*, the causal agent of black leaf streak, were inoculated *in vitro* into the tissue of banana leaves. Adding *M. fijiensis* triggered the synthesis of the following polyamines: agmatine, nor-spermidine, spermine, spermidine and putrescine. The presence of peroxidase, polyphenol oxidase and lipoxygenase enzymes altered the injury-response levels to which
Overcoming Constraints to Sustainable Adoption of Good Management Practices in Local Banana Production in the Philippines in the Midst of Changing Climate

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Keywords: Adaptive management, farming systems, climate change

Banana is the most economically important and dominantly planted fruit crop in the Philippines, but its potential contribution to the country’s food security, nutrition and poverty alleviation is yet to be fully realized. Despite numerous projects undertaken, the government’s target for improved yields for local banana cultivars has not been reached. Local cultivars are planted in about 90% of the total banana hectarage accounting for 60% of total production. Amongst more than 90 local cultivars, ‘Cardava’ (or ‘Saba’), ‘Lakatan’ and ‘Latundan’ comprise 55% of the total production. Local banana production is predominantly small-scale, low-input and low-yielding. Existing traditional practices of small growers inadvertently contribute to the spread of destructive pests and diseases, and climatic disturbances recurrently devastate local banana producing areas in Luzon and Visayas. Whilst the recommended package of technology (POT) for local bananas has been demonstrated to work, small growers notably find difficulty in fully implementing it. This paper will consolidate lessons from various projects in validating the POT under farmers’ management, assessing the POT’s component technologies considering social, technical, economic, environmental and policy concerns, identifying constraints and implementing workable strategies that facilitate adoption of improved production practices for local bananas. This paper proposes a farming systems approach to push forward a sustainable local banana production that concurrently address effective transfer of adaptive management skills and buffering the resource-limited, risk-averse, small-scale farmers against bananas’ inherent vulnerability to climatic extremes and uncertainties, the occurrences of which are predicted to be more intense and more frequent with impending climate change.
Mapping Banana and Plantain Production Zones in Latin America and the Caribbean

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Keywords: Mapping, banana, plantain, participatory, methodology, GIS

Banana and plantain are key crops for many smallholders in Asia, Africa and Latin America and the Caribbean (LAC). Mapping of production zones is an important step to support the sustainability of these crops. Even with many technological advances in terms of remote sensing and spatial analysis, there remains significant uncertainty on where banana production zones are located, especially for smallholder production. An effort to map all banana production zones in LAC was conducted by Bioversity International and CIAT, using expert knowledge combined with GIS (Geographical Information Systems) tools. Maps for many countries were completed, allowing different analysis using specific models, like Ecocrop which evaluates suitability of a location for a crop. Coupled with a participatory mapping methodology, we have now obtained a basic information source, within the frame of the project: “Improving the quality of life of rural communities in five countries in Latin America and the Caribbean, through technological innovations in production, agro processing and marketing of bananas”. Significant advances have been achieved in mapping plantain production zones particularly in Dominican Republic, Nicaragua, Panama and Venezuela. These maps and related information will be available online through a regional knowledge platform hosted by the Plantain and Banana Research and Development Network for Latin America and the Caribbean, MUSALAC. Although the level of precision should be improved, the generated information is valuable and could be considered as the first step for developing detailed maps and for performing essential analysis to help successfully address many of the challenges facing banana and plantain production and marketing in LAC. Additional efforts are needed to link this initiative to other mapping projects, especially to find homologue conditions that allow applying technologies and results concerning analogue areas.
Role and Constraints of Banana Production in South-Western Nigeria

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Keywords: Musa, farmers, plantain, value addition, technology adoption

The south-western region of Nigeria is an important banana production zones. The diverse uses of the crop have made it a key dietary staple, and some cultivars are being processed for soap-making (from the peel) and used as medicinal herbs (from the leaves and bracts). However, the bulk of production is still concentrated in the hands of poor farmers, who lack necessary resources. As a follow up to a study on analysis of banana processing businesses, a survey was conducted in the south-western Nigeria (Oyo, Ondo, Ekiti and Osun states) with the aim of: (1) examining the factors limiting production within the zone; (2) assessing the adoption level of improved cultivars; and (3) assessing available production technologies and levels of value addition among banana farmers and their families. Data collected revealed that 81.5, 53.7, 42.5 and 62.8% of the farmers in Oyo, Ondo, Ekiti and Osun states, respectively, engaged in banana production primarily because they serve as source of food. An average of 98.4% in all the states engaged in banana production because it serves dual purpose as source of food and income. It was further revealed that almost all parts of the plant are used while inadequate planting materials, declined soil fertility, and diseases and pests ranked highest amongst the constraints to field expansion. The majority of farmers (71.5%) were not aware of sucker cleaning or multiplication techniques.
Sigatoka Leaf Spot Epidemiology of ‘Prata-Anã’ on the Coastal Tablelands, Sergipe, Brazil

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Keywords: Musa spp., Mycosphaerella musicola, diseases

Banana grows in all Brazilian regions under a range of climates and soil conditions. Many diseases of regional importance occur at high rates, contributing to reduced productivity and fruit quality. The aim of this work was to analyze the temporal distribution and epidemiology of Sigatoka leaf spot (also called yellow Sigatoka, caused by Mycosphaerella musicola) infecting cultivar ‘Prata-Anã’ (AAB) in the Northeastern Brazilian Coastal Tablelands. The evaluations were carried out with 22 different genotypes at the experimental field of Embrapa Coastal Tablelands at Nossa Senhora das Dores, Sergipe, Brazil. The experimental design was a randomized block with three replicates; each plot consisted of four plants. The infection rate (IR) of ‘Prata-Anã’ was correlated with the environmental variables: precipitation (PP), mean temperature (TM) and days after planting (DAP). The progress curves were done by regression analysis with data from 60 to 210 DAP (period 1), and from 240 to 420 DAP (period 2). For period 1, a significant positive correlation was verified between IR and DAP (y = 0.05x + 6.6392; r² = 0.577), and a negative correlation between PP and IR (y = -0.0446x + 17.468; r² = 0.8205). For period 2, IR was negatively correlated with TM (y= -5.5881x + 164.77; r² = 0.9254) and positively with DAP (y = 0.1702x - 35.826; r² = 0.8524). However, there was no significant correlation between PP and IR. It was observed during this period that the disease progress occurred under decreasing mean temperature conditions. During this period there was a positive correlation between DAP and IR, indicating that the disease progressed throughout the evaluation period.

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Sporulation and Mycelial Growth of *Mycosphaerella musicola* Leach on Different Culture Media

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**Keywords:** *Musa* spp., yellow Sigatoka, *Pseudocercospora musae*

*Mycosphaerella musicola* Leach, causal agent of Sigatoka leaf spot in bananas is well known as a recalcitrant pathogen in terms of mycelia growth and sporulation on culture medium. As conidia are crucial for detailed plant-pathogen interaction studies, reliable methods for their production are highly demanded. In this work, mycelial growth and sporulation of *M. musicola* were evaluated on different culture media [agar, potato dextrose agar (PDA), malt-agar and V8-agar]. For sporulation, a Petri dish containing 20 ml of culture medium was used, having been dispensed a 700 ml spore suspension. For the mycelial growth experiment, fresh and dry weights of mycelium were evaluated from the means of five colonies. Cultures were incubated at 25°C ± 1°C during 12 hours photoperiod. The experiments were arranged in a randomized design with three replicates per culture medium and two biological repetitions in both assays. Eight evaluations for counting conidia were performed by means of a Neubauer haemocytometer with a 10 ml suspension. Culture media, which are poor in carbon and nitrogen, such as vegetables extracts (juices), decoction (tea) or tissue, preferably obtained from hosts of the pathogen, are recommended for stimulating sporulation. The V8-agar medium showed better production of conidia (26.26 x 10⁴ conidia/ml suspension) while higher mycelial growth was registered on PDA, malt-agar and V8-agar, respectively.

Acknowledgement: CAPES/ FAPITEC
Epidemiological Measurements in Banana Genotypes Inoculated with *Mycosphaerella musicola*

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**Keywords**: Disease, progression curve, Sigatoka

In order to define the most important variables in disease progression, it is necessary to know the details of the monocycle of the pathogen. Incubation periods and establishment of Sigatoka leaf spot, caused by *Mycosphaerella musicola*, are strongly influenced by climatic factors and by genotype. Therefore, in this study, evaluations consisted of variables of the monocycle of two isolates of *M. musicola* originating from Lavras-Minas Gerais state and Cruz das Almas-Bahia state. The dynamics of infection were registered in different banana genotypes (‘Grande Naine’, ‘Prata Anã’, ‘Calypso’, ‘Preciosa’, ‘Japira’ and ‘PA-4244’) which were artificially inoculated in leaves 1 and 2. After inoculation, plants were kept inside a greenhouse at Embrapa Cassava and Fruits. The shorter incubation and latency periods were found in susceptible cultivars (‘Grande Naine’ and ‘Prata Anã’); ‘Grande Naine’ was the most susceptible cultivar, showing the largest areas under the disease severity progression curve, confirming its susceptibility to Sigatoka leaf spot. Resistant genotypes, ‘Preciosa’, ‘Japira’ and ‘PA-4244’, are promising for commercial plantations in regions with favourable climatic conditions for the development of Sigatoka leaf spot. Although the experiments were carried out at different periods of the year, the strain from Cruz das Almas was more aggressive compared to the one from Lavras-MG.

*Acknowledgement: CAPES/FAPITEC*
Reaction of ‘Prata Anã’ Banana Genotypes to Sigatoka Leaf Spot in Planaltina, DF, Brazil

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Keywords: Genotype resistance, yellow Sigatoka, Pseudocercospora musae, Mycosphaerella musicola

The Brazilian Cerrado region has a great potential for fruit crop production, so one of the goals of Embrapa’s Banana Breeding Programme is to prospect genotypes that are adapted to this region, presenting high yields and resistance to some of the most common diseases of this important crop. Therefore, the objective of this work was to evaluate six banana genotypes (‘Garantida’, ‘PA 42-44’, ‘PA 94-01’, ‘FHIA-18’, ‘Maravilha’ and ‘Prata Anã’) from subgroup ‘Prata Anã’ for their reaction to Sigatoka leaf spot (also called yellow Sigatoka, caused by Mycosphaerella musicola), the most common foliar disease of banana in the world. The field trial took place in Embrapa Cerrados (Planaltina, DF, Brazil) from August 2009 to January 2011. The experimental design used was a completely randomized block, with three replicates/genotype and six plants/replicate. The five oldest leaves, with no senescence symptoms, were evaluated on each plant every 15 days, using a modified Stover’s diagrammatic scale that ranged from 1 (< 1% foliar surface with symptoms) to 6 (> 51% foliar surface with symptoms). The mean area under disease progression curve (AUDPC) of each genotype was calculated and compared by Tukey’s Test (P<0.05). ‘Garantida’ (692.7) and ‘PA 42-44’ (864.9) had the best performance, presenting an AUDPC value significantly lower than ‘PA 94-01’ (1083.6), ‘FHIA-18’ (1111.4), ‘Maravilha’ (1352.9) and ‘Prata Anã’(1522.8). These data, together with information about the production cycle, yield and other agronomical aspects, will help banana growers in the Cerrados region in the decision-making process.
Efficiency of Citric-Biomass Extract, Fungicides and Leaf Removal in Mycosphaerella Leaf Spots Control

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Keywords: Sigatoka, alternative fungicide, AUDPC

Mycosphaerella leaf spots caused by Mycosphaerella fijiensis and Mycosphaerella musicola are the main leaf diseases in banana crops in southern Brazil. Usually disease control is based on fungicide applications preceded by leaf removal, while some farmers use only leaf removal. The objective of this research was to evaluate the efficiency of fungicides, citric-biomass extract and leaf removal to control Mycosphaerella leaf spots in banana crops grown in a subtropical climate. The experiment was developed in a commercial banana crop of cultivar ‘Prata Dwarf’ (AAB genome), in the southern coast region of Santa Catarina State, from August 2008 to November 2008. The treatments tested were: T1) control; T2) leaf removal; T3) tebuconazole (0.5 L/ha) alternated with thiophanate methyl (0.6 ml/ha) without leaf removal; T4) tebuconazole (0.5 L/ha) alternated with thiophanate methyl (0.6 ml/ha) with leaf removal, T5) citric-biomass extract (1.0 L/ha) without leaf removal; T6) citric-biomass extract (1.0 L/ha) with leaf removal. Disease was quantified through the area under disease progress curve (AUDPC), final gross sum (GSfinal) and disease curves. The experimental design was randomized blocks in a factorial scheme with five replicates. The Duncan multiple range test ($P<0.05$) was used for comparisons among treatments on AUDPC and GSFinal. Fungicides and citric-biomass extract resulted in significant reductions in AUDPC and GSfinal, but leaf removal alone had no significant effect. Fungicides and citric-biomass extract reduced AUDPC by 65 and 63%, and GSfinal by 87 and 73%, respectively. Disease curves were consistent with AUDPC and GSfinal, showing the effect of fungicides and citric-biomass extract on controlling Mycosphaerella leaf spots.
Potential of Enzyme Inhibition as an Alternative Method for the Control of Black Leaf Streak in Bananas and Plantains

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\textbf{Keywords:} Fungicide resistance

BIOPHYTOMAX is a patented method based on extracellular enzyme inhibition. It acts on pathogen microorganisms that produce extracellular, degradative enzymes by inhibiting such enzymes that degrade plant cell walls and furnish substrate for the microorganism. When such enzymes are inhibited, the pathogen does not receive its needed substrate and stops its growth. Disease development is stopped. As BIOPHYTOMAX does not act directly on the microorganism and is not a killing agent, it is neither aggressive nor toxic to the user or the environment. In addition, it will avoid resistance development. BIOPHYTOMAX is to be used as an alternative and complementary treatment for integrated control. It can be mixed with fungicides or used in rotation with some fungicides to reduce resistance pressure. It can be used in organic programs. The non-toxicity of BIOPHYTOMAX on banana trees and the complete inhibition of \textit{Mycosphaerella fijiensis} growth have been validated at lab scale. Different single-leaf tests show an efficacy similar to Tridemorph\textregistered and better than Mancozeb\textregistered. At the small-plot trials level, a significant decrease in disease development and a significant increase in leaf production are measured.

Essential Oils in the Control of Black Leaf Streak\textbf{ (\textit{Mycosphaerella fijiensis} Morelet)}

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\textbf{Keywords:} Antifungal activity, alternative control, banana disease

Black leaf streak is considered the most damaging and costly banana disease, because its control accounts for about 30\% of total production costs. The disease affects the leaves of banana plants, quickly destroying the foliage if
effective control measures are not applied. The use of synthetic chemicals as
fungicides is the primary control method of fungal diseases. Alternative control
methods for black leaf streak have received little attention, because of the
availability of highly effective fungicides, as well as the limited interest and
financial support to find alternative control methods. However, the
development of strains less sensitive or resistant to systemic fungicides, and the
increasing demand for environmentally safe control measures has increased the
interest in finding alternatives for controlling black leaf streak. Vegetable
extracts and essential oils have been used to control fungal diseases. The
biological activity of certain vegetable extracts and essential oils against
Mycosphaerella fijiensis Morelet (the pathogen causing black leaf streak) were
studied. The oils were extracted by steam drags, after drying the vegetable in
the greenhouse with air circulating at 45°C. Two concentrations of oils were
used: 10µl and 30µl/ml of medium. Only Carapa guianensis (andiroba) and
Copaifera officinalis (copahiba) were used in natura. Incubation was realized at
25°C, for 7 days. The essential oils of Carapa guianensis (andiroba), Copaifera
officinalis (copahiba), Syzygium aromaticum (clove), Eucalyptus globules
Labil. (Eucalyptus) and Thymus vulgaris L. (thyme) were shown to inhibit
conidium germination of M. fijiensis. The level of inhibition was dependent on
oil concentration.

Surveying for Banana Viruses in East Africa and Improved
Diagnostics for the Detection of Banana Streak Viruses (BSV)
in Banana (Musa spp.)

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Keywords: Rolling circle amplification, polymerase chain reaction,
endogenous badnavirus, diagnostics

Bananas are infected by a number of banana streak virus (BSV) species,
including four recognised species, with at least six other distinct species
reported. Integrated copies of the viral DNA from four of these species occur in
the genome of Musa accessions which contain a B genome, and these can be
activated to cause infections. Diagnosis of infectious, episomal BSV in bananas
is complicated by the significant serological and genomic diversity amongst the
different species reported, and because integrated sequences result in false
positives when PCR is used for detection. Recently, we developed a rolling-
circle amplification (RCA) assay which can discriminate between episomal and
integrated BSV-DNA. This RCA method was compared with BSV-specific
polymerase chain reaction (PCR) to detect BSV in field samples from Uganda,
Kenya and Tanzania. Leaf samples were collected in Uganda (121), Kenya (41)
and Tanzania (26). These were assayed for BSV using both RCA and BSV-
specific PCR, as well as Banana bunchy top virus (BBTV) using PCR and both
Cucumber mosaic virus (CMV) and Banana bract mosaic virus (BBrMV) using
RTPCR. BBTV and BBrMV were not detected, while CMV was detected at
one site in Kenya. In contrast, BSV was common and widespread in both
Uganda and Kenya. For BSV with no known integrated counterparts, RCA and
PCR were equivalent methods for BSV detection. This was also the case for
BSV with integrated counterparts, where the cultivar did not possess a B-
genome complement. However, in cultivars with a B-genome complement,
many more samples were positive using PCR compared to RCA, suggestive of
positive results due to integrated BSV sequences and not due to episomal virus
infection. In these cases, RCA was a much more reliable method for BSV
detection. The results show that PCR-based diagnostics for BSV are
satisfactory in A-only genome cultivars or where integrated sequences are not
known in B-genome cultivars, but caution must be exercised where integrated
sequences are known to occur.

Previously Unrecognised Banana Streak Virus Species Detected
in Regional Musa Germplasm of East and Central Africa

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Keywords: Banana streak virus, species, rolling-circle amplification,
germplasm transfer

Bananas host several banana streak virus (BSV) species. Three BSV
species are recognised based on complete sequences. Six tentative new species
of Banana streak UA virus (BSUAV), Banana streak UI virus (BSUIV),
Banana streak UL virus (BSULV), Banana streak UM virus (BSUMV), Banana
streak CA virus (BSCAV) and Banana streak IM virus (BSIMV) have been
completely sequenced. The high serologic and genomic variability of BSV, compounded by integration of Badnavirus sequences into the Musa genome, has presented enduring diagnostic challenges. The immune-capture polymerase chain reaction (IC-PCR) or immune-sorbent electron microscopy (ISEM), currently used cannot detect the whole range of BVS species. Rolling-circle amplification (RCA) was developed by Queensland University of Technology (QUT) for BSV detection. RCA is sequence independent and can amplify circular DNA molecules including all episomal forms of BSV. RCA was used to detect BSV from 51 of the 356 samples collected from the regional Musa germplasm of East and Central Africa. BSV species detected were confirmed by PCR using specific primers developed from DNA generated in RCA. The germplasm was established using cultivars collected from East Africa, the International Transit Centre (ITC), Leuven, Belgium and IITA. Previously recognised BSV species such as Banana streak OL virus (BSOLV) and Banana streak Mysore virus (BSMyV) were detected in 6 of the 25 samples of bananas collected from Uganda, the rest being tentative new species of BSUAV, BSUIV, BSULV and BSIMV. BSV species detected in imported germplasm were distinctly different from those in local germplasm. Detection of these unrecognised species would not have been possible using antisera and primers developed using recognised BSV species. Most studies on BSV have been limited to characterization but the spread and virulence of different BSV species are largely unknown. It is important to use a system that detects all BSV species for certifying banana germplasm for international movement to minimise introduction of new BSV species to new areas.

**Induction of Resistance to Infection by Fusarium oxysporum f. sp. cubense in Banana Pre-Inoculated with Gigaspora margarita**

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**Keywords:** Panama disease, systemic acquired resistance, mycorrhiza

Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* (Foc), is a limiting factor for banana crop production. The most effective control measure is use of resistant cultivars. Considering the difficulties of transferring
Fusarium wilt resistance to susceptible cultivars, widely preferred by consumers, induced resistance is an alternative to be evaluated in this plant pathosystem. Therefore acibenzolar-S-methyl (ASM) and DL-β-amino-n-butyric acid (BABA) were evaluated as elicitors of systemic acquired resistance (SAR) in banana plantlets of cultivars ‘Maçã’ (AAB) and ‘Grande Naine’ (AAA), inoculated with Gigaspora margarita and challenged by inoculation with Foc under greenhouse conditions. Banana plantlets were sprayed with SAR elicitors 100 days after inoculation with G. margarita and inoculated with Foc by immersion of the roots in an inoculum suspension containing $1 \times 10^3$ conidia/ml, for one hour, 4 weeks after applying SAR elicitors. The disease severity was evaluated 20 days after inoculation. Foliar spray application of either BABA or ASM did not show any effect on severity of Fusarium wilt in banana plantlets. Severity of Fusarium wilt in ‘Maçã’ (0.81) and ‘Grande Naine’ (0.29) was very low. ‘Maçã’ had significantly higher shoot dry biomass (12.0 g), primary root dry biomass (4.57 g) and radicle fresh biomass (31.86 g) than ‘Grande Naine’, which had 8.72 g shoot dry biomass, 3.65 g primary root dry biomass and 23.99 g radicle fresh biomass.

Production of Beauvericin and Fusaric Acid by Fusarium oxysporum f. sp. cubense, the Causal Agent of Fusarium Wilt in Banana

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Keywords: Panama disease, phytotoxins

Fusarium wilt, caused by the fungal pathogen Fusarium oxysporum f. sp. cubense (Foc), is one of the most destructive diseases of banana. Twenty strains of Foc race 1 and race 4 were isolated from the epidemic regions of Guangdong, Hainan, Guangxi, Fujian and Yunnan provinces, China. Their secondary metabolites were analyzed and some characteristic fingerprinting signals were captured by high-performance liquid chromatography - electrospray ionization ion trap - mass spectrometry (HPLC-ESI-MS). Among them, two primary phytotoxins were fusaric acid (FA) (179 Daltons) and another compound with a molecular weight of 783 Daltons, which was then purified and identified as beauvericin (BEA) by $^1$H-nuclear magnetic resonance chromatography ($^1$H-NMR). In vitro experiments showed that both beauvericin and fusaric acid could lead to rotting of the banana pseudostem or cause banana plantlet wilting. The pathogenic virulence of 20 Foc strains was tested, and the
contents of two toxins in plant roots, pseudostems and leaves were examined. It was found that the more virulent the Foc strain, the higher toxin content in the host plant. These results provide a solid basis for further elucidation of the pathogenicity of Foc in banana.

Severity of Fusarium Wilt in Four Banana Genotypes under Different Inoculum Concentrations of *Fusarium oxysporum* f. *sp. cubense*

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**Keywords:** Panama disease

Fusarium wilt, caused by *Fusarium oxysporum* f. *sp. cubense* (Foc) is one of the most destructive diseases in banana (*Musa* spp.) worldwide. The main effective strategy of disease control is the use of resistant varieties. The selection of resistant genotypes is one of the most critical stages in breeding programs. Under field conditions, the selection may take up to 3 years (or more), making it very costly. Previous research at CNPMF was conducted under greenhouse conditions to develop a methodology of selecting Foc-resistant genotypes. The aim of this study was to optimize this methodology, to evaluate the inoculation efficiency of inoculum produced on corn meal and to study the influence of Foc density on screening for Fusarium wilt resistance. Six-month old plantlets of four genotypes (‘Apple’, ‘Tropical’, ‘Grande Naine’ and ‘Thap Maeo’) with varying resistance levels (highly susceptible, moderately susceptible, resistant and resistant, respectively) were inoculated with Foc. The inoculum was produced on a substrate containing corn-meal:sand (1:1) and their concentration adjusted to 101, 102 to 107 CFU/gram of soil, with sterilized water. This compost allowed the formation of chlamydospores and increased the number of macroconidia per gram of substrate. Ten grams of each concentration were placed into holes surrounding the bananas seedlings, at 10 cm depth. This work was carried out in a complete randomized experimental design, with ten replicates per treatment. The disease severity was evaluated 45 days after inoculation based on a rating scale, and the averages of the external and internal symptoms were calculated. For both evaluations (internal and external symptoms), the concentration of 106 CFU/gramme of soil allowed the differentiation of genotypes regarding the level of resistance. The changes
in the methodology proposed in this work have potential use in studies involving the Foc-banana pathosystem, in assessing the pathogenic variability of Foc, in evaluating potential biocontrol agents and in selecting genotypes with resistance to Fusarium wilt under greenhouse conditions.

**Status of Xanthomonas Wilt of Banana in Kenya**

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**Keywords:** *Xanthomonas campestris* pv. *musacearum*

Bananas are a major staple crop in the East African region, produced mostly by smallholder farmers. Its production in East Africa is however threatened by the presence of a devastating disease, Xanthomonas wilt. The disease is caused by a gram-negative, flagellated, xylem bacterial pathogen, *Xanthomonas campestris* pv. *musacearum* (Xcm). The disease was first reported in Ethiopia in 1968 affecting Ensete (*Ensete ventricosum*, Musaceae), a close relative of banana. Later, an outbreak on banana plantations was reported in Uganda in 2001, Democratic Republic of Congo in 2003, Rwanda in 2004, Tanzania in 2005 and Kenya in 2006. Infected plants show leaf yellowing and complete wilting, and eventually die. When the pseudostem(s) of a Xanthomonas wilt-infested banana plant is cut transversely, a pale yellow bacterial ooze will appear within 5-15 min. Fruits show rusty brown stains, rotting and are rendered inedible. The disease spreads very fast mainly by insect pollinators, contaminated farm tools and infected planting materials. In 2010, a national Xanthomonas wilt survey was conducted to establish the status and spread of Xanthomonas wilt in Kenya. The survey involved 500 farms covering five major banana-growing regions in Kenya according to acreage. The areas varied according to different agro-ecological zones: areas where the disease has already been reported, threatened areas where the disease is advancing and free areas where the disease has not reached. Results confirmed the presence of Xcm in 23 districts as compared to four districts reported in 2006 from two major regions “Western and Nyanza” provinces of Kenya which produce over 60% of the total national banana production. The presence of Xcm was not detected in the remaining regions. Out of 500 farms sampled, 51 samples of banana plants which were suspected to be affected with Xanthomonas wilt were collected. The samples
were taken for molecular diagnosis for Xanthomonas wilt using a PCR machine with a diagnostic primer 38R (5’CAGCGGCGCCGTTGTATTGAGTG3’) Xcm 38F (5’CCGCCGGTCGCAATGTGGGTAAT3’). Ten samples were positively diagnosed to have Xanthomonas wilt. The disease is present in western parts of Kenya and is spreading very fast. An aggressive Xanthomonas wilt awareness-raising campaign targeting banana farmers, along with quarantine measures are recommended to check further disease spread. Initiated and ongoing research on sustainable Xcm management could save the Kenyan banana industry.

Effect of Collecting Frequency on the Population of Banana Weevils (Cosmopolites sordidus and Metamasius hemipterus) with Pseudostem Traps

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Keywords: Banana beetles, management, manual collection, banana crop

The study assessed the comparative effectiveness of daily and weekly collecting frequencies in controlling levels of banana weevil borer (Cosmopolites sordidus) and stripped banana borer (Metamasius hemipterus), using pseudostem “cheese” traps (where fermented sap exudate from cut pseudostem bases attracts the weevils). The experiment was conducted in two separate areas of 2 ha each, in 3-year old banana plantations of the cultivar ‘Pacovan’, in the municipality of Limoeiro, State of Ceará, Brazil. Adults of both weevil species were collected on a daily and weekly basis, over a 21-day period, encompassing 21 daily collections and 3 weekly collections for each area and each weevil, with a total of 40 “cheese” traps, 20 for each area. After the 21-day period, 10 traps for each collecting frequency were assessed for the number of larvae and pupae of C. sordidus and M. hemipterus in the internal tissues of the superior and inferior parts of the traps. After this counting, fresh traps were prepared from pseudostems of plants no longer than 30 days after harvest. Results allowed the following conclusions: 1) Higher numbers of adults of both weevil species were obtained in daily collections within the 21-day period, compared with the weekly collecting; 2) Despite the high number of insects collected, mainly C. sordidus, there was no population decrease; 3) The presence of larvae and pupae in the inferior and superior part of traps suggest that females of C. sordidus lay their eggs in rhizomes and pseudostems, even after fruit-harvest. No larvae or pupae of M. hemipterus were collected from inferior
and superior part of traps. The results of this study show that more frequent trapping increases weevil control levels.

**Evaluation of Different Types of Traps for Integrated Management of Banana Root Borer**

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**Keywords:** *Cosmopolites sordidus*, pseudostems banana traps, infestation level, planned control

The root borer (*Cosmopolites sordidus* Germ., 1824) is an important pest of banana. The incorrect use of chemical insecticides has increased pest intensity rather reducing it. This work aimed to test two different traps developed from banana pseudostems to verify its efficiency (attractiveness and durability) as a strategy and tool for the integrated management of this pest. Experiments were performed on a commercial banana farm of the cultivar ‘Nanicão’ (AAA, Cavendish group) localized in the Central-West region of Brazil. Traps evaluated were: “tile” - a piece of pseudostem (40 cm long), cut longitudinally, placing the cut edges on the soil, and “cheese” - a pseudostem cut off at 30 cm above soil level with another cut in the middle. The experiment was conducted using a completely randomized block design, with five replicates and 60 traps per plot. The data were statistically analysed with T-tests at 5% significance-levels. Results suggest that the attractiveness and durability of the “cheese” traps were significantly higher than that of “tile” traps. In the first evaluation, 7 days after traps installation, the numbers of insects captured in “cheese” traps were three times higher those in the “tile” traps. However, 15 days after installation, the attractiveness of both traps declined. The “tile” traps decreased by almost 100%, showing a durability of less than 15 days. The “cheese” traps continued attracting insects, but with reduced effectiveness (about 42% reduction). This work suggest that both for weevil monitoring and control, the use of “cheese” traps is more effective, as they are better at trapping the insects, but that they become less effective after 15 days.
Successful *In Vitro* Rearing of Banana Weevil (*Cosmopolites sordidus*) on an Artificial Diet and the Potential for Rapid Screening of Genotypes for Weevil Resistance

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**Keywords**: Artificial diet, *Cosmopolites sordidus*, rapid resistance screening

Artificial insect diets are used to rapidly establish the effectiveness of chemical-based strategies to control insect pests. In addition to enabling preliminary evaluation of active compounds, artificial diets also allow *in vitro* study of growth cycles, particularly at larval stages, which are usually inaccessible. Further, diets allow laboratory handling of insects and produce larger, consistent numbers throughout the year, independent of the host plant. Banana weevils previously lacked such diet. With no known artificial diet for banana weevils, insect rearing required considerable space and use of field-collected banana stems to maintain insects in the lab. The artificial diet for banana weevil in this study was developed basing on one recently reported for sweet-potato weevils *Cylas puncticollis* (Boheman) and *Cylas brunneus* F. (Coleoptera: Brentidae) in which the sweet-potato powder was replaced with banana corm powder. Subsequently, powders from different cultivars with known resistant response to the banana weevil were evaluated. This study reports on the successful development of a diet that has shown satisfactory laboratory rearing of the weevils to the adult stage in 48 days compared to 36 days in the natural banana stem diet. It also reports on the use of this diet to evaluate the power of different genotypes as a novel method for resistance screening. Genotypes Calcutta-4 (AA), Cavendish (AAA) and Kayinja (ABB) showed 0-35% of adult emergences compared to 65% in susceptible genotypes. In conclusion, the diet created will not only serve rapid bioassay experimentation to screen potential candidate proteins or molecules for a transgenic approach but also shows potential for rapid screening of genotypes for weevil resistance.
Thrips Species (Insecta: Thysanoptera) Associated with Banana (Musa spp.) in Santa Catarina State, Brazil

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Keywords: Identification, Frankliniella brevicaulis, Bradinothrips musae

The State of Santa Catarina is the third largest banana producer in Brazil, with approximately 6000 banana farmers. Thrips are among the main banana pests. Thrip damage considerably reduces the commercial value of the fruit. This research aimed to identify the thrips species associated with banana in eight cities in Santa Catarina state (Corupá, Garuva, Guaramirim, Itajaí, Luis Alves, Rio dos Cedros, Schroeder and Tijucas). Bunches of bananas with typical symptoms of thrips attack were collected from August 2007 to September 2010 and transported to the Laboratory of Entomology Epagri /Itajaí Experiment Station, where adults were separated and stored in 2-ml microtubes containing alcohol 70%. Then the material was sent to the Esalq/USP´s Department of Entomology and Acarology for identification. The preparation of the specimens and microscope slides assembly followed the methodology of Mound & Marullo (1996). Species identification was made through appropriate taxonomic key, and the specimens were kept at the Museum of Entomology, Esalq / USP. The identified species were Frankliniella brevicaulis Hood, 1937 and Bradinothrips musae (Hood, 1956). Frankliniella brevicaulis was found in Corupá, Garuva, Guaramirim, Itajaí, Luis Alves and Schroeder. Bradinothrips musae was identified in samples from Tijucas and Rio dos Cedros. This is the first record of B. musae on banana in Santa Catarina state, Brazil.
Keynote: The *Musa acuminata* Genome Sequence, a New Template for Banana Genetics

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We produced a reference genome sequence of banana. The *Musa* accession selected for sequencing is a doubled haploid of the accession ‘Pahang’ (DH-Pahang). This accession belongs to the *Musa acuminata* species (AA genome) *malaccensis* subspecies. We generated 20.5x coverage of the 523 Mb genome of DH-Pahang (estimated by flow cytometry) using paired and single 454 reads, complemented by Sanger plasmid- and BAC-End Sequences. An additional ~50x coverage of Illumina shotgun data was produced in order to ensure a high-quality sequence draft. The assembly, performed with Newbler software, covers 472.2 Mb, representing 90% of the genome of DH-Pahang. A high-density genetic map was produced using SSR and DArT markers that enabled anchoring 70% of the assembly in 11 pseudo-chromosomes. We identified 36,542 protein-coding gene models using a reconciliation approach, taking ESTs, protein sequences and *ab initio* data as input. Progress on the characterization of the sequence will be presented, considering its potential to support *Musa* genetics and breeding. This project is carried out in the framework and with the participation of partners of the Global *Musa* Genomics Consortium.
Brazil is the fifth global banana producer, yielding 7 million tons in 2009 from approximately 500,000 hectares. Main cultivars are highly susceptible to black leaf streak and many are also susceptible to Sigatoka leaf spot. Fusarium wilt, nematodes, the banana weevil and Moko bacterial wilt also threaten Brazilian bananas. Banana streak viruses (BSVs) and Cucumber mosaic virus (CMV) are also present. Developing pest- and disease-resistant cultivars through germplasm selection, or generation of new cultivars via hybridization, are considered the most efficient means of control. Banana genetic breeding began at Embrapa Cassava and Fruits in 1983, mainly improving AA diploids, then crossing with triploids and tetraploids generating AAB hybrids and AAAB tetraploids, and then generating AAB triploid and AAAB tetraploid hybrids of the Prata and Silk types. The program breeding objective is to develop higher-yielding, earlier, more nematode- and disease-resistant, dwarf varieties, producing fruits with Prata and Silk flavour. Since 1983, Embrapa has built a comprehensive germplasm collection, housing 274 accessions whose genomic groups are divided as follows: AA 35%, AAB 21% AAA 20%, AAAB 8%, ABB 4% and AAAA 3%. Embrapa Cassava and Fruits also has 42 improved diploids, including first and second generation diploids which are resistant to Sigatoka leaf spot, black leaf streak and Fusarium wilt. The entire germplasm has been morphologically and molecularly characterized by microsatellite (SSR) and DArT markers. In vitro maintenance is carried out, and exchange activities occur through shoot-apex micropropagation. The breeding program at Embrapa uses two strategies for developing banana hybrids: i) hybridization involving improved diploid and triploid parents, and ii) using tetraploid hybrids as female parents and improved diploids as male parents. After hybridization, seeds are germinated in seedbeds or submitted to embryo rescue, via tissue culture. Plantlets acclimatize in plastic bags and are then field
evaluated. The breeding program is divided into five stages: i) one pit or one single seed, ii) clonal stage, iii) Fusarium wilt-resistance evaluation, iv) black leaf streak resistance evaluation, and v) a network trial in different Brazilian edaphoclimatic conditions. Over 28 years, the Embrapa banana program has recommended 13 cultivars, and also recommended the two most important cultivars in Brazil, ‘Prata Anã’ and ‘Pacovan’. The release of a Fusarium wilt (race 1) and Sigatoka leaf spot-resistant Prata type or apple banana (AAAB) hybrid (BRS Platina) is expected in 2012. Embrapa also selects superior hybrids using molecular biology and tissue-culture tools. Molecular techniques, genomics, proteomics and bioinformatics are accelerating banana genetic breeding. Recent genome sequencing has provided a wealth of data for both biodiversity studies and gene discovery. Embrapa also uses ISSR and SSR markers to analyse genetic diversity of accessions in its banana genebank. By using NGS (outsourced), we aim to begin studying gene expression (mainly disease complexes). With qRT-PCR using the released banana genome sequence databank, we will broaden our view and application of marker-assisted selection for obtaining new banana varieties resistant to main diseases.

**Keynote: Conventional Banana and Plantain Breeding**

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**Keywords:** 2n gametes, DNA markers, inter-specific hybridization, *Musa*, ploidy manipulations, tissue culture, transgenics

Cross-breeding of banana and plantain brings new challenges to the genetic improvement of crops due to ploidy and high sterility of most popular cultivars. This article provides an overview on the state of the art on banana and plantain breeding: from assessing *Musa* diversity for genetic enhancement, to working with farmers and end-users to ensure the adoption of newly-bred hybrids. It also provides details on the approaches used and steps throughout the breeding process: crossing, screening, testing, selecting and identifying promising hybrids for further cultivar releases. This manuscript highlights the genetic knowledge accumulated in this crop that will facilitate the use of new approaches in its improvement. Banana and plantain breeding programs may incorporate genetic engineering and genomics-led breeding to enhance their effectiveness particularly under a changing climate that will affect crop yields.
Status of Global Programs in Accessing Improved *Musa* Germplasm - An Indian Case Study

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**Keywords:** International *Musa* Testing Program, national partnerships

Various national and international breeding programs have resulted in the release of more than 25 superior hybrids, and efforts are still in progress. The battle is half won when high-yielding hybrids are produced and is complete when they are adopted by the farmers for their livelihood. Bioversity International-France is instrumental in developing a network for the distribution of improved global hybrids and India is one of the beneficiaries. NRCB, Trichy, India, as the nodal centre for the International *Musa* Testing Program (IMTP), evaluated many hybrids. The results showed that the introductions ‘Bluggoe’, ‘Burrow Cemsa’ and ‘Saba’, despite their greater rating for vascular discolouration, performed well and yielded good bunches indicating their tolerance to Fusarium wilt race 2. Screening for Mycosphaerella leaf spot resistance (*Mycosphaerella* spp.) revealed that the exotic hybrids ‘TMB-5295-1’, ‘FHIA-18’, ‘CRBP-39’ and ‘FHIA-21’ were resistant to *Mycosphaerella eumusae*. Superior hybrids and clones, ‘FHIA-01’, ‘FHIA-03’, ‘FHIA-21’, ‘FHIA-23’ and ‘Saba’, were further subjected to multilocation testing under the All India Coordinated Research Programmes (Tropical Fruits) under NARS. A follow-up program on evaluation of global hybrids in farmers’ fields, partially supported by BAPNET, has multiplied and supplied ‘FHIA-03’, ‘FHIA-21’ and ‘FHIA-23’ to various farmers. ‘FHIA-01’ was found to be more suitable for processing with high sugar-to-acid ratio and low polyphenol oxidation, which otherwise leads to pulp browning. ‘FHIA-03’ and ‘Saba’ have been popularly accepted by the consumers as cooking bananas. ‘FHIA-21’ failed to impress due to its high susceptibility to pseudostem weevil despite its high yield potential. The dessert variety ‘FHIA-23’ is still being evaluated as a substitute for local Cavendish clones. Many hybrids have been found promising and are under commercial cultivation. This paper briefly describes the status of introduced germplasm and their extent of utilization in India.
Evaluation of Pollen Fertility of Diploid and Doubled-Diploid Clones of Mlali and Their Potential Use for Banana Breeding

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Keywords: \textit{Musa acuminata}, gamete fertility, breeding

Past phylogenetic studies pointed out some Mlali clones (AA) as the 2N gamete donor parent of Cavendish (AAA) and Gros Michel (AAA) varieties, revealing their potential for \textit{Musa} breeding. Nevertheless, cultivated bananas are usually known to be highly sterile at diploid and triploid levels, making banana crosses difficult. Therefore, it is necessary to investigate the floral biology of these Mlali clones to determine their capacity to generate progenies by crosses. Pollen fertility of both diploid and doubled-diploid Mlalis (as donor of diploid gametes) was evaluated by different approaches. At anthesis, Alexander staining technique has shown that up to 70\% of haploid and diploid pollen was viable. Pollen viability was confirmed in test crosses with \textit{Musa} wild accessions presenting no fertility problems. These results were then correlated with post-meiotic observations at the tetrad stage: 70\% were regular tetrads in the diploid and doubled-diploid clones whereas the remaining cells were aggregated under forms of pentads and hexads, and more rare heptads leading probably to aborted microspores. Fine observations of the irregular tetrads suggested that meiotic errors occurred during both first and second mitosis of the meiosis. These preliminary results suggest that doubled-diploid Mlali clones (AAAA) might be useful male parents with high breeding potential for the synthesis of new disease-resistant AAA export bananas.

Improvement of Cavendish Varieties through Conventional Breeding

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Keywords: Female fertility, Cavendish re-synthesis, triploid x triploid crosses

In their article “Banana breeding, polyploidy, disease resistance and productivity”, Stover and Buddenhagen (1986) reported the results of
evaluating female fertility of Cavendish varieties. The authors reported that the pollination of a few hundred bunches of ‘Valery’ and other Cavendish clones with pollen from diploids never yielded seed. From these results, the authors concluded that the apparent seed sterility of Cavendish varieties (without any research to determine or overcome the blocks) precluded their use as female parents in conventional breeding programs. The scientific community accepted these observations as a fact and did not carry out additional tests because the commercial varieties of banana for export, such as ‘Grand Naine’, ‘Williams’, ‘Dwarf Cavendish’ and ‘Valery’ are all triploids and parthenocarpic. The triploid condition causes these varieties to produce many sterile eggs, and the process of parthenocarpy allows for the development of fruit without ovule fertilization. On the basis that Cavendish varieties have low fertility, the Banana and Plantain Breeding Programme of FHIA started in 2002 the pollination of 20,000 bunches of Grand Naine and Williams varieties with pollen from ten male parents for the development of tetraploids females. As a result of this effort, FHIA obtained 200 seeds with 40 embryos, from which 20 tetraploid hybrids were developed. These results prove that Cavendish varieties are not sterile, but that they do have low fertility. The fact that they are not 100% sterile greatly facilitates the use of conventional breeding methods to create new progenies. The selected tetraploids progenies were pollinated with pollen from the improved diploid FHIA SH-3142. As a result of this cross, two hybrids resistant to black leaf streak and *Fusarium oxysporum* f. sp. *cubense* race 1 have been preselected. These hybrids have the same plant height, cycle, aroma and taste of the Cavendish banana. The color of the pseudostem, the leaf architecture and the shape of the fingers are different from Cavendish.

**Breeding Pisang Awak - Screening of Best Female Parents, Donor Parents and Compatibility Studies**

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**Keywords:** Fertility, seed set

Pisang Awak is a hardy subgroup of *Musa*, valued for nutritional and economic security. High yield potential, dual utility as cooking and dessert fruits, adaptability to marginal conditions and higher altitudes and cold tolerance attributed this group as a ‘Poor Man’s Banana’. Despite all these good qualities, their high susceptibility to Fusarium wilt race 1 and Xanthomonas wilt warrants improvement of this group. NRCB has a collection of 34 Pisang
Awak types which were screened for female fertility and found that >96% are fertile. They were evaluated for their ability to produce hybrid seeds, tested for embryo viability, embryo regeneration and evaluation of progenies. Eight *Musa acuminata* diploids (AA), both parthenocarpic and non-parthenocarpic, were used as pollen parents. Out of the 34 Pisang Awak types, only 13 (38%) were found to be excellent female parents with seed production ranging from 4 to 459 seeds/bunch. Among them, Bankela, Enna Benian and Nepali Vannan produced 200-400 seeds/bunch; Ankur, Eni Komban and Udhayam produced 100-200 seeds/bunch; while <100 seeds were produced from Agni Malbhog, Boothi Bale, Chinia, Deshi Kadali, Karpuravalli, Nepali Vannan and Poombidiyan. Among the female parents, Ankur, Bankela, Udhayam, Enna Benian and Nepali Vannan exhibited a broad spectrum of crossing ability with more than four pollen parents. Among the eight diploid pollen parents, Pisang Jajee, Calcutta-4 and Chengdawt were found to be better than the others in terms of crossing ability, extent of seed set, embryo germination and hybrid regeneration. Results also showed that embryo viability is not a true reflection of its regeneration capacity which indicated the possible role of post-embryo developmental inhibitors. This paper deals in detail with Pisang Awak parents, their attributes, amenability for improvement and possible success in regeneration of hybrid progenies.

**Development of Dwarf Plantain Hybrids with Resistance to Black Leaf Streak and High Yield: Lessons Learnt and Outlooks**

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**Keywords:** Dwarfism, breeding, banana, *Musa* ssp., diploid, triploid, tetraploid

Plantain (*Musa*, AAB group) is an important food and cash crop in the humid lowlands of Sub-Saharan Africa, Central/South America and the Caribbean where it is mainly cultivated by smallholders. Plantain is threatened by severe diseases and pests and generally exhibits weak root branching. Nematode and weevil attacks weaken the anchoring of the plant, thus increasing its susceptibility to strong winds. Therefore, dwarf, robust and resistant cultivars seem to offer an appropriate and environmentally friendly solution for sustainable yield improvement. A breeding strategy based on multisite hybridizations allowed the identification of 50 seed-fertile plantain
cultivars. Pollination of several French-type plantains by diploid banana (AA group) has resulted in the production of diploid, triploid and tetraploid hybrids. On average, seed set was higher when plantains were pollinated during the dry season. The dwarf plantain ‘Red Yade’ produced numerous viable seeds at middle altitude (400 masl) whereas it appears totally sterile at sealevel. When pollinated by the wild diploid banana ‘Calcutta 4’, this dwarf plantain landrace generated mainly dwarf tetraploid hybrids with black leaf streak resistance and higher female fertility. In addition, very few dwarf diploids and triploids were generated. Although tetraploid hybrids express periodically streaks caused by banana streak viruses (BSV), they produce a normal bunch. Among the predominant triploids resulting from crosses between dwarf tetraploid and improved diploids, several hybrids exhibited dwarf stature, black leaf streak resistance and big bunches. Hence, the dwarfism in ‘Red Yade’ appears to be a stable and genetic trait. These results show that a dwarf banana with big bunches can be created by conventional breeding and opens prospects for generating appropriate segregating populations for genetic analysis of dwarfism in banana. Promising dwarf hybrids which do not express symptoms of BSV will be shared as parental clones or as final products with the international community.

**Synthesis of New Interspecific Triploid Hybrids from Natural AB Germplasm in Banana (Musa sp.)**

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**Keywords:** Musa breeding, interspecificity, polyploidy

The release of new, sweet-acid banana varieties resistant to Sigatoka and Fusarium wilt is important for domestic markets in tropical and subtropical countries. Common current breeding strategies consist of selecting tetraploid AAAB new hybrids directly from crosses between AAB sweet-acid varieties pollinated with AA clones carrying resistance genes. However, this cross pathway is hampered by low gamete fertility and the rare occurrence of desired 2N gametes on the AAB female side (N= X = 33 chromosomes). We propose an alternative pathway which aims to create new triploid hybrids directly from AB landraces. Natural AB clones are sterile but their AABB tetraploid counterparts obtained by colchicin treatment are fertile. This gamete fertility was made profitable in crosses with AA and BB accessions to generate AAB and ABB hybrids. We present here our results on the agronomic value of various progenies involving an *in vitro* synthesized tetraploid Kunnan (AABB) and several AA and
BB clones. These first results suggest a very high potential of this new strategy for the release of well-performing new hybrids combining productivity, disease resistance and fruit quality. Hybrids with a high added-value, issued from this strategy could be made available for evaluation within the ProMusa network.

**Planet of the Cavendish – Understanding the Domination**

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**Keywords:** Banana, cultivars, marketing

Those seeking to bring change to varieties sold in the banana markets of the world have encountered major difficulties over the years. Change has been sought because of production difficulties caused by banana diseases such as Fusarium wilt or a desire to invigorate a stagnant market and get the edge via the introduction of diversity of product. Currently the world banana scene is dominated by cultivars from the Cavendish subgroup with their production in excess of 40% of total world production of bananas and plantains combined and in most western countries Cavendish is synonymous with banana. But Cavendish production usually necessitates frequent and regular applications of pesticides, particularly fungicides for Sigatoka leaf disease control. So genetic resistance to these and other diseases would be very beneficial to minimising costs of production as well as reducing health risks to banana workers and the general population and minimizing impacts to the environment. In recent years the overall market sales of some crops such as tomatoes has increased by providing diversity of varieties to consumers. Can the same be done for bananas? Perhaps a better understanding of the current situation, how we have arrived at where we are now and the forces at play will allow us to plan more strategic crop improvement research which has enhanced chances of adoption by the banana industries of the world. We undertook a scoping study to determine current market opportunities for alternative varieties in Australia and provide a roadmap for the industry to successfully develop this market. Our multidisciplinary team reviewed the literature, surveyed the supply chain, analysed gross margins and conducted consumer and sensory evaluations of ‘new’ cultivars. This has provided insight on why Cavendish dominates the market, which is the focus of this paper, and we believe will provide a solid foundation for future progress.
Oral presentations - Theme 2: Non-conventional plant breeding

Keynote: Understanding Plant Immunity: Transcriptome Profiling in Musa-Pathogen Interactions Using Next Generation Sequencing

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Keywords: Plant immunity, Musa acuminata, Mycosphaerella musicola, 454 transcriptome sequencing

The development of novel approaches for crop protection requires continued advances in our understanding of the molecular mechanisms controlling plant immunity. Molecular and genomics tools have advanced our understanding, with two key branches currently recognized. In one, plant innate defense is governed by PAMP-triggered immunity (PTI), following host recognition of pathogen-associated molecular patterns (PAMPs). Successful pathogens can, however, suppress PTI signaling through evolution of specific effector proteins. In response, plants have co-evolved cytoplasmic resistance (R) protein receptors that establish effector-triggered immunity (ETI) - a second immune-system branch which recognizes specific pathogen-effectors. Although banana (Musa spp.) is one of the world’s most important edible crops, contributing towards food security, a comprehensive transcriptomic dataset is not yet available for use in accelerated molecular-based breeding. In order to develop a functional genomics resource for this crop which reveals transcriptional changes during plant immunity responses to biotic stresses, we performed a pyrosequencing study of expressed genes in Musa acuminata during compatible and incompatible reactions with the fungal pathogen Mycosphaerella musicola, causal organism of Sigatoka leaf spot. Total RNA samples were prepared from whole plant leaf material from ‘Calcutta-4’
(M. acuminata ssp. burmannicoides - resistant) and ‘Grande Naine’ (AAA, Cavendish - susceptible), both uninfected and artificially challenged with pathogen conidiospores. Full-length enriched cDNA libraries were sequenced using a 454 GS-FLX system pyrosequencer with Titanium chemistry, generating 978133 raw sequencing reads, with an average length of 334 bp and totalling over 460 million bp. Over 35,000 unigenes were assembled for each genotype, with approximately 70% displaying no significant identity to any sequences in the public databases. In silico analysis identified differentially expressed genes associated with stresses and response to biotic stimuli. Datasets were exploited for identification of expressed resistance gene analogs and defense genes, as well as large scale SSR marker development. These resources will contribute to our understanding of plant immunity processes in Musa, facilitating disease management based upon genetic improvement.

Keynote: Development of Bananas with Enhanced Levels of Pro-Vitamin A through Genetic Modification

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Bananas are essentially ubiquitous in the developing countries of the wet tropics, where they are an important dietary component and, in some instances such as in Uganda, are a staple food. In the same regions, micronutrient deficiencies remain a major public health problem, despite well-established strategies such as food fortification and micronutrient supplements. An alternate strategy to reach these micronutrient-deficient populations is to supply micronutrients in staple foods by developing cultivars with enhanced levels of the target micronutrients, a process known as biofortification. Bananas are an excellent target for biofortification. We are using a genetic modification strategy to develop bananas with enhanced levels of pro-vitamin A (PVA) and iron. The program is essentially two parallel projects with initial technology development in Australia for enhancement of PVA and iron levels in banana fruit, using Cavendish as the model, with continuous technology transfer to Uganda where micronutrient enhanced East African highland bananas are transformed, regenerated and trialled. The first stage of the program has involved testing a range of potential promoters and transgenes to identify the
most suitable combinations to generate bananas with at least a four-fold increase in PVA. The first Australian GM banana field trial was established in early 2009 with first fruit analysed in 2010. In this initial trial, three transgenes were tested: a phytoene synthase gene \((Apsy2a)\) from the high-PVA Fe’i banana ‘Asupina’; the phytoene synthase 1 gene \((Zmpsyl)\) from maize, and the carotene desaturase gene \((CrtI)\) from Erwinia uredovora, under the control of either constitutive promoters or the fruit-preferred banana expansin 1 promoter. In the best lines, fruit PVA at harvest was increased more than ten-fold with constitutive promoters controlling the expression of either \(psy\); greater than five-fold increases were also achieved when \(psy\) was under the control of the expansin 1 promoter.

**Mining of Musa ECT Databases for the Development, Validation and Characterization of EST-SSRS**

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**Keywords:** Sequencing

Expressed Sequence Tags–Simple Sequence Repeats (EST-SSRs) are highly informative markers due to their existence in transcribed region of genomes, which may lead to the development of gene-based maps and increase the efficiency of marker-assisted selection. In this study, *Musa* ESTs available in the NCBI were used for identification of EST-SSRs. The retrieved sequences were assembled using CAP3 analysis. The assembled sequences were used to evaluate the presence of SSR motifs by using the free software available on the website. Among the EST-derived SSRs, the tri-nucleotides were the most frequent followed by di-nucleotides. The length distributions of all SSRs indicated that the frequency of repeats decreases exponentially with repeat length. *In silico* analysis was also carried out to find out the polymorphism in length of SSR repeats, and results suggested that maximum polymorphism is observed in di-repeats. The ESTs which contain only SSRs were annotated by BLASTX and BLASTN. Primers were synthesised from the sequences hit with putative genes responsible for resistance-related mechanism specifically and validated in the different resistant *Musa* accessions maintained at the National Research Centre for Banana, Trichy. The validation of EST-SSR primers revealed that polymorphism was observed among the banana cultivars. The polymorphism was further confirmed by cloning and sequencing of amplified
alleles, and revealed that allelic differences could be attributed mainly to differences in repeat types and length in the microsatellite regions. A total of 13 EST-SSR primers were tested against different parental combinations. Among these, SSR2 primer, which has been designed from stress response regulator genes, showed polymorphism between parents ‘Matti’ and ‘cv. Rose’. For this preliminary study it was understood that using more Musa EST-SSR primers will lead to molecular tagging of resistance genes and to constructing the linkage map for Musa.

**A Cyclind2;1 Ortholog Isolated from Banana Enhances Root Growth**

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**Keywords:** Genetic transformation, genome walking, Musa spp., root growth

A long crop cycle is one of the factors limiting productivity of the banana crop. However, low seed fertility in banana and the lack of breeding lines limit the application of conventional breeding in shortening the growth cycle. Genetic transformation with cDNA encoding CyclinD2;1-type sub-protein enhanced growth in model plants. To explore the applicability of molecular breeding to banana, we verified the presence of a CyclinD2 ortholog in the banana plant and tested whether the gene could confer growth traits. In this study, we isolated a full-length cDNA of banana encoding a CyclinD2;1 protein subunit from an East African highland banana cultivar ‘Nakasabira’ (AAA) using the RACE and genome walk methods. The 1032-bp open reading frame for the protein was found in all banana cultivars and wild Musa species sampled. Expression profile linked the cyclin in banana to meristematic tissues. The 344-amino-acid sequence had typical cyclin N- and C-terminal domains, an LLCAE retinoblastoma related protein-binding motif at the N-terminus and a banana characteristic IWKVHAHY signature motif. Amino-acid sequence comparison revealed a 40%, 54%, 57% and 57% identity with Arabidopsis, rice, maize and wheat CyclinD2;1, respectively. A gene construct of the Cyclin was made with a constitutive Caulifower Mosaic Virus (CaMV) 35S promoter
and over-expressed in banana cultivar ‘Sukali Ndiizi’ (AAB). A transgenic banana line with high levels of CyclinD2;1 expression and a doubled root-growth rate, compared to the control, was obtained.

**Expression Profiling of Root-Lesion Nematode Responsive Genes in Banana Cultivars**

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**Keywords**: Semi-quantitative RT-PCR, upregulation, Musa

Root-lesion nematode (*Pratylenchus coffeae*) is an important pest in banana, with an average yield loss estimated to be around 44.4% in ‘Nendran’. Developing nematode-resistant banana cultivars will enhance sustainable production of bananas. Hence this present study was undertaken to identify the genes involved in nematode-resistance mechanisms through molecular breeding approaches. Cultivar ‘Karthoobiumtham’, which is identified as a *P. coffeae*-resistant accession, was used to identify the genes induced in roots after nematode infestation through suppression-subtractive hybridization. From the SSH library which consists of 1400 clones, 680 clones were sequenced. The assembly of sequences led to the formation of 256 unigenes. These unigenes were annotated and classified into different categories. Primers were designed from the EST sequences which were hit with putative defense/resistance related genes for studying the expression profile of the genes in resistant and susceptible cultivars. The semi-quantitative reverse-transcriptase polymerase chain reaction (RT-PCR) analysis was carried out in the cDNA synthesised from *P. coffeae*-infested root samples over a range of time intervals and from un-infested root samples. The result suggested that most of the genes are constitutively expressed in both cultivars, but expression levels are higher in resistant cultivars compared with susceptible cultivars. In general, the expression levels of genes involved in defense and in signal transduction were higher than those of other types of genes. Genes involved in phenyl propanoid (chalcone synthase and polyphenyl oxidase) and jasmonic biosynthesis (liposygenase) pathways and metallothionein were upregulated in both resistant and susceptible cultivars, whereas the level of expression was high in resistant cultivars. Full-length gene isolation of three upregulating ESTs for further characterization is in progress. In conclusion, the findings of this study have contributed to the GeneBank database resources for Musa and have opened some insights in molecular mechanisms controlling the biochemical and physiological responses of banana roots to *P. coffeae* infestation.
Banana Cultivar ‘Rasbale’ (Syn. Rasthali) Transformed with AMP Gene Evaluated for Fusarium Resistance


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In an attempt to genetically modify banana cultivar ‘Rasbale’ (syn. ‘Rasthali’, AAB, Silk), one of the favoured cultivars of Southern India which is highly susceptible to infection by *Fusarium oxysporum* f. sp. *cubense* (Foc) race 1, embryogenic cell suspensions of the cultivar were transformed with an antimicrobial peptide gene cloned in-house from *Allium cepa* seeds, and the construct developed in pCAMBIA 2301. Around 62 original transformants were produced. Transformants from the first batch (28 in number) which tested positive for integration of the gene by PCR, RT-PCR and Southern Blot, were further multiplied by micropropagation. The expression level of the transgene Ace-AMP1 was tested by ELISA using a gene-specific antibody developed in guinea pigs. Plants with levels higher than 30 ng/g leaf were selected for root challenging with Foc in pots. The inoculum was prepared on sterilized sorghum grains for 2 weeks at 28°C. Plants were root-challenged with Foc inoculum (150 g/plant) in two replicates along with non-transgenic controls. The scoring of disease was according to the extent of leaf yellowing, wilting and stem splitting (0 = no symptoms - 5 = stem base splitting) (Nasir et al., 2003). The scores were converted into percent disease index (PDI). Of the 25 root-challenged transgenic plants, 7 plants showed 0-20 PDI, 8 plants 20-40 PDI and the rest 80-100 PDI. Except for the 7 plants with a PDI of 0-20, all the rest progressively succumbed to the disease over a 7-months observation period. Non-transgenic plants succumbed to the disease within a month. The 7 plants showing 0-20 PDI were multiplied for further field testing. A second batch of 34 remaining original transformants is being evaluated according to the same protocol.
Genetic Engineering of East African Highland Bananas: Unravelling Opportunities for Multiple Genetic Trait Improvement

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**Keywords:** Genetic transformation, *Agrobacterium*, embryogenic cell suspension

East African highland bananas (EA-AAA) constitute a staple food crop for the East African region. In Uganda, 80\% of the population depends on bananas (Matooke) as a major source of food. These banana cultivars have minor genetic differences and a narrow gene pool. The development of genotypes resistant to key production constraints is complicated by sterility, triploidy and long generation cycles. Moreover, a few hybrids so far generated have inferior culinary quality than the EA-AAA landraces. Genetic engineering, with genes that have potential resistance against diseases, has been reported mainly in plantains and dessert bananas. Due to recalcitrance of EA-AAA banana cultivars to somatic embryogenesis, their genetic transformation was considered untenable. Recently, we developed high-quality embryogenic cell suspensions (ECSs) of a few EA-AAA cultivars and an efficient transformation system of these bananas. *Agrobacterium tumefaciens* strains EHA105 and/or AGL1 containing the binary vector pCAMBIA1305.1 or pFAJ3000 were used in this study. Vector pCAMBIA1305.1 contained an \textit{hpt} gene as a selectable marker and \textit{Gusplus} as a reporter gene; whereas pFAJ3000 contained \textit{nptII} and \textit{gusA}, respectively. Regenerated lines were transgenic, based on PCR analyses. Southern blot analysis confirmed that \textit{gusA} gene was integrated in the genome with various integration patterns. Observed transformation frequencies and regeneration were compared with results obtained from transformation of ‘Sukali Ndizi’ (AAB), used as model cultivar in our transformation system. These results have opened opportunities for the genetic engineering of EA-AAA banana cultivars for a wide range of traits including resistance to nematodes and banana bacterial wilt, iron storage capacity and enhanced provitamin A levels.
The Biosafety Regulation and Experiences of Conducting Transgenic Banana Confined Field Trials in Uganda

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Keywords: GMO crops, biosafety assessment, black leaf streak

Delivery of pest-resistant crop varieties is central to integrated pest management and sustaining banana productivity for resource-poor subsistence farming in Africa. The National Agricultural Research Organization (NARO) of Uganda has adopted modern biotechnology to complement conventional breeding of banana, a very important staple in Uganda and the East African region. Under a project funded by the Agricultural Biotechnology Support Programme (ABSP-II), the government of Uganda and Bioversity International, capacity was built to field-evaluate genetically modified (GM) bananas developed at the Catholic University of Leuven (Belgium). Being a signatory to the Convention on Biological Diversity (CBD) and its Cartagena Protocol on Biosafety, Uganda is required to establish legal mechanisms to regulate research and use of living modified organisms obtained by recombinant gene technology. While the government was developing the legislation, NARO and partners were able to achieve approval to import transgenic banana plants and conduct a confined field trial. The banana plants were genetically modified to express the chitinase enzyme conferring resistance to black leaf streak disease caused by Mycosphaerella fijiensis, a leaf disease that reduces banana yields by up to 50%. In laboratory challenging studies, some lines showed immunity levels against black leaf streak and this needed to be confirmed under field conditions. This paper outlines the regulatory process that was followed for the trial approval, experiences both for NARO, development partners and the associated government agencies and how these experiences contributed to faster approval of two subsequent GM banana trials, one for biofortified banana and another for resistance to bacterial wilt. The paper further discusses the implications for further development and eventual release of transgenic crops in Uganda and the region.
Short oral presentations (in support of a poster)

Analysis of Genetic Diversity and Population Structure of *Musa* Accessions Based on Molecular Markers

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**Keywords:** Breeding, evolution, genome

Information about ploidy, genomic composition, genetic diversity and population structure of *Musa* accessions is critical for planning breeding strategies. Thus, 224 banana accessions were analyzed using 16 SSR loci under two approaches. First, SSR data were analyzed as a dominant marker using the Jaccard similarity index followed by clustering by Neighbour-Joining. Allelic data were also considered to establish genetic relationships between accessions with multiple ploidy using the Structure software. Genomic composition and/or ploidy determined by SSR confirmed previous classification by morphological descriptors, except for ‘Marmelo’, ‘Pitogo’ and ‘Pisang Nangka’. Clustering analysis divided accessions according to ploidy, genome and subgroup. The approach based on Structure identified \(k=21\) and corroborated, in general, the classification established by clustering analysis. In general, diploids were more heterogeneous in relation to ancestry, while cultivar ancestry was easily assessed in tetraploid hybrids from breeding programs.

A Simple and Robust Approach for Genotyping in Musaceae

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Banana and plantain (*Musa* spp.) are seed-sterile, vegetatively propagated crops, which originated as intraspecific hybrids of *Musa acuminata* and
interspecific hybrids between *M. acuminata* and *Musa balbisiana*. To set up an efficient strategy for breeding improved banana varieties, and support the choice of crossing parents, a solid understanding of the genetic diversity of available resources is needed. The rich genetic diversity of this crop is, however, endangered by diseases, adverse environmental conditions and changed farming practices. This underlines the need for characterization and preservation of genetic diversity. With the aim to provide a simple and robust approach for genotyping in *Musa*, we have developed an optimized genotyping platform using SSR markers. The genotyping system is based on 19 microsatellite loci, originally developed by CIRAD, which are scored using fluorescently labeled primers and high-throughput capillary electrophoresis separation with high resolution. The knowledge gained during the course of this study is used by the *Musa* Genotyping Centre, which serves the *Musa* research and breeding community by determining DNA ploidy and SSR profiles of unknown samples. The Centre operates on a cost-recovery basis, and guarantees that all analyses are performed under strictly controlled conditions, enabling direct comparison of various accessions from different parts of the world.

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**SSR Mining in 454 Transcriptome Sequencing-Derived *Musa acuminata* Unigenes**

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**Keywords:** SSR markers, genetic improvement, 454 transcriptome sequencing

Massively parallel pyrosequencing-based transcriptome analysis is an efficient approach for large-scale functionally relevant gene-derived SSR discovery. The objectives of this study were to identify SSR loci in unigene sequences generated using 454 transcriptome pyrosequencing, and verifying predicted gene function and *in silico*-derived differential expression. cDNA libraries were prepared from total RNA material extracted from leaf material in ‘Calcutta-4’ (*M. acuminata* ssp. burmannicoides) and ‘Grande Naine’ (AAA, Cavendish), both uninoculated and inoculated with *Mycosphaerella musicola* (the causal agent of Sigatoka leaf spot). ‘Calcutta-4’ is a wild diploid widely
used as a donor of biotic stress resistance genes in conventional breeding programs for improved polyploids. cDNA libraries for each challenged genotype were submitted to 454 sequencing, with 24,246 and 23,729 contigs identified for ‘Calcutta-4’ and ‘Grande Naine’, respectively. *In silico*-based gene function prediction was made against the NCBI Genbank database. Contigs were analysed for SSRs using the program mreps and flanking primer pairs designed using Primer3. A total of 4098 and 4096 SSR loci, where flanking primers could be designed, were identified in ‘Calcutta-4’ and ‘Grande Naine’ datasets, respectively. From these, 75% are associated with unigenes coding proteins with known function, 0.13% (11) with unigenes potentially involved in defense or stress responses, and 96% associated with genes differentially expressed under conditions of infection and non-infection by *M. musicola*. Overall, microsatellites were present in 24% of unigenes with predicted function. Marker validation in *M. acuminata* diploid material contrasting in resistance to black leaf streak and Sigatoka leaf spot is currently ongoing. The microsatellites identified, particularly those associated with genes potentially involved in defense or stress responses, will serve as useful tools for employment in *Musa* genetic improvement programs.

Agronomic and Molecular Characterization of Gamma-Ray Induced Banana (*Musa* spp.) Mutants Using a Multivariate Statistical Algorithm


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**Keywords:** Selection of descriptors, multivariate analysis

Globally, bananas play a key role in market trade and are especially used as main food source for low-income populations. In Brazil, bananas are mainly consumed as fresh fruit, occupying the second largest internal market. Nevertheless, this crop has few productive commercial varieties with good agronomic characteristics available. The objective of this study was to evaluate the genetic variability in putative banana ‘Pacovan’ (AAB, subgroup Prata) mutants submitted to gamma-ray irradiation, using a set of agronomic and molecular data (ISSR markers). Approximately 200 *in vitro* buds of ‘Pacovan’ cultivar were irradiated with $^{60}$Co. The dose was 20 Gy with rates of 1.322 kGy. For each cultivar, ten buds were used as controls, without exposure to $^{60}$Co. The irradiated buds were transferred to a basic MS medium and maintained in growth chambers under controlled temperature of 27 ± 2°C and a
16-hour photoperiod. Plants were submitted to subcultures of 30-day intervals. After four subcultures, plants were rooted in MS medium supplemented with 0.25 mg/L of naphthalene acetic acid and 8 g/L of agar with pH adjusted to 5.8 and maintained under the same conditions mentioned above. Approximately 1200 irradiated rooted plants and 600 rooted control plants were taken to a screenhouse and acclimatized in dibble tubes containing Plantmax and in screenhouses with 50% sombrite with light control and irrigation by automatic mist. A pre-selection was carried out at the screenhouse using the selection criteria of plants with height inferior to the control in at least 10%. Only these plants were evaluated in the field during two production cycles. From this selection, 179 irradiated 'Pacovan' plants, along with 36 controls were characterized agronomically and molecularly. The distance between the putative ‘Pacovan’ mutants varied from 0.26 to 0.64 with a co-phenetic correlation coefficient, using molecular and agronomic data, of 0.7669. Four mutants were selected based on best agronomic characteristics and height. Data also showed that variability can be explored after irradiating ‘Pacovan’ banana mutants, and used in banana breeding to develop new dwarf varieties that also present good agronomic characteristics. The combined dataset procedure was carried out using the Gower algorithm, which uses molecular and agronomic data together in a single dataset.

**Analysis of Gene Expression in *Musa acuminata* during Compatible and Incompatible Interactions with *Mycosphaerella musicola***

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**Keywords:** Sigatoka

Sigatoka leaf spot, caused by the fungus *Mycosphaerella musicola*, causes significant disorder of leaf area and premature fruit ripening in banana. The development of genotypes resistant to fungal pathogens via crop improvement is of fundamental importance. In this context, we analysed gene expression in ‘Grande Naine’ (AAA, Cavendish group - susceptible) and *Musa acuminata* ssp. *burmancicoides* ‘Calcutta 4’ (resistant) leaf material, uninoculated and inoculated *in vivo* with pathogen conidiospores. Total RNA was extracted and purified using Concert™ and cDNA prepared using the Kit SuperScript™ II
Reverse Transcriptase (Invitrogen). A pyrosequencing study using a 454 GS-FLX system with Titanium chemistry generated 978,133 raw sequencing reads. Over 35,000 unigenes were assembled for each of ‘Calcutta-4’ and ‘Grande Naine’. Of the unigenes identified, 1,908 were identified in silico as potentially involved in defense and biotic stress responses. In order to compare transcriptional activity in NBS-LRR resistance gene analogs (RGAs) in *M. acuminata*, during *in vivo* interactions with *M. musicola*, primers for reverse transcriptase (RT) PCR were designed using Primer3plus and targeting contig exon sequences. Constitutive primers were designed for the *M. acuminata* actin gene (gi 151413782) and elongation factor (gi 66775523) in the NCBI database. RT-PCR results have revealed examples of constitutive gene expression in both compatible and incompatible interactions across the infection time course, as well as a complete absence of gene expression. Examples of RGAs showing similar expression patterns in compatible and incompatible interactions were also apparent, with susceptible and resistant cultivars, for example, showing low levels of expression in the early infection stages and up-regulation in late stages. In contrast, another RGA displayed constitutive early expression in the resistant cultivar, strong down-regulation in the intermediate infection stage, and recovery to higher levels in the final stage examined. This project will contribute to elucidation of mechanisms of resistance and defense in *Musa*. Candidate gene application via plant transformation or marker assisted selection will benefit *Musa* breeding programs for the generation of resistant genotypes.

**Transgenic Bananas with Resistance to Fusarium Wilt Race 1**

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Fusarium wilt, caused by *Fusarium oxysporum* f. sp. *cubense* (Foc), is one of the most important diseases of bananas. It is divided into races based on host range and also by vegetative compatibility grouping (VCG). Foc race 1 infects a wide range of Gros Michel banana cultivars and is present in virtually all banana-producing countries. Importantly, the primary export banana, Cavendish, is resistant to Foc race 1. In Australia, Lady Finger (AAB) is susceptible to Foc race 1, limiting the production of this cultivar. Foc is extremely difficult to control as there are no effective fungicidal treatments and it remains in infested soil for decades. The most appropriate control is through the use of resistant cultivars. We are using genetic modification to add Foc
resistance to currently accepted cultivars. We have previously demonstrated that
genes that inhibit programmed cell death or apoptosis in animals are effective in
increasing the efficiency of Agrobacterium-mediated transformation of bananas
through the inhibition of programmed cell death induced by A. tumefaciens. These
genes were transformed into both Lady Finger (race 1 susceptible) and
Cavendish (race 1 resistant), regenerated and multiplied. The transgenic Lady
Finger lines were challenged in the glasshouse using a small-plant assay and Foc
VCG 0124/5. Three different anti-apoptosis genes, Bcl-xL, Ced-9 and Bcl-23’
UTR, under the control of the maize polyubiquitin promoter were tested. Seven
transgenic lines (2 x Bcl-xL, 3 x Ced-9 and 2 x Bcl-2 3’ UTR) showed
significantly less internal and external disease symptoms than the wild-type
susceptible Lady Finger banana plants used as positive controls with one line
having resistance equivalent to the Cavendish control. We have demonstrated that
anti-apoptosis genes can confer resistance against Foc race 1 in banana,
suggesting that induction of programmed cell death is a key component of
successful Foc infection in banana.

Advances in Integrating Conventional and Molecular
Breeding to Improve East African Highland Banana Fruits
for Pests and Pro-Vitamin A Concentration

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Keywords: Hybrids, cell suspension, biofortification, genetic engineering

East African highland bananas are an important staple food and cash crop
in the Great Lakes region of Africa. In Uganda, Rwanda, Burundi, the Eastern
Democratic Republic of Congo and the Bukoba region of Tanzania, the crop
occupies more than 30% of utilized arable land. The perennial and all-year-
round fruiting nature of the banana makes it a valuable food and income
security crop for communities who subsist on small land holdings. In terms of
utilization, it is estimated that per capita consumption in a country like Uganda
is over 200 kg/year. Furthermore, the widespread use of banana presents an
opportunity for using them as a delivery vehicle for micronutrients such as
vitamin A whose deficiency in rural areas causes health problems and is
challenging to deliver. Despite this importance, banana-producing communities
face serious challenges of pests and diseases that severely limit productivity.
The National Agricultural Research Organization (NARO) in partnership with
the Queensland University of Technology is undertaking research to improve the East African highland banana for increased provitamin A levels using a genetic engineering approach. One of our strategies is to biofortify conventionally improved East African banana hybrids. An advanced banana hybrid (M9) with moderate resistance to weevils, nematodes and black leaf streak was identified and targeted for biofortification with pro-vitamin A. A cell suspension system of the hybrid was developed and transgenic lines generated. Additionally, the hybrid was recently released as KABANA 6 (or Kiwangazi) and is being promoted to potential end-users. When fully developed, the biofortified banana hybrid will help address the problem of vitamin A malnutrition in rural areas and will be easier to adopt because of its resistance to pests and diseases.

Large-Scale Adoption of Improved Plantains: The Impact of FHIA-21 in the Dominican Republic

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Improved hybrid varieties of banana and plantain for managing biotic and abiotic stress and increasing productivity have been disseminated in many countries. Although some of these hybrids have shown good performance and yield potential for many environments, evidence for large-scale adoption and acceptance on national markets is scarce. This study assesses the impact of the hybrid FHIA-21 in the Dominican Republic and analyses the factors that facilitated acceptance on national markets and adoption among farmers. Data collection included a household survey with a randomized sample of 182 farmers in the country’s most important growing region, the Cibao valley, and interviews with key informants from the public and the private sectors involved in research, extension and business related to plantains. Results show that adoption of FHIA-21 in the Cibao valley is high: 64% of survey respondents are now growing FHIA-21, and of these adopters, 60% also continue cultivating the local varieties. Comparing yields for respondents who grow both FHIA-21 and the traditional triploids, with similar crop management, results show significantly higher yields for FHIA-21, with 20-25 t/ha versus 15-18 t/ha for the traditional varieties. Farmers reported their
positive perceptions about resistance of FHIA-21 to black leaf streak under a range of climate conditions. On the fresh markets, FHIA-21 is widely accepted, although prices are about 30-40% lower. Factors for this development were found to be: a) the national public investment in research as a response to black leaf streak disease pressure, b) the collaboration between research institutes and the processing industry and c) the strong preference for plantain as a staple in the Dominican Republic. The results emphasize the importance of agricultural policy, market conditions and even the personal engagement of key actors in research and private sector to enable and facilitate the large-scale adoption and impacts of new technologies, such as plantain hybrids.

How Can a Network like MusaNet help in Facilitating Exchange of Musa Genetic Resources?

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Keywords: Diversity, evaluation, information, conservation

A comprehensive understanding of the existing Musa diversity and its potential uses, is crucial, not only to genebank curators, molecular biologists, breeders, phytopathologists and other Musa researchers, but also to the rural households most dependent on the crop for their food and income. The Musa genetic resource community developed the implementation of the global Musa genetic resources conservation and use strategy, and has recently launched the global Musa genetic resources network, MusaNet. The network strives to improve the conservation and safe dissemination of Musa genetic resources, and also seeks to fill the gaps in our knowledge of the Musa genepool through increased characterization and multi-locational evaluation efforts. MusaNet will enhance the utilization of genetic resources and therefore support their conservation. The function of MusaNet is to mobilize diverse expertise and
perspectives, define priorities and build consensus around an agreed agenda for joint action. Expertise is mobilized through four thematic groups: i) Genetic diversity, taxonomy and characterization, ii) Germplasm evaluation; iii) Germplasm information and documentation and iv) Germplasm conservation. Linking those thematic groups with the four Musa regional networks will assure that conservation and sustainable use will be at global, regional and national levels. Indeed, without rational management of genetic resources we may lose them irremediably. Comprehensive conservation and sustainable use of Musa genetic resources can only take place if all banana-producing countries agree to share their resources and information. MusaNet will help genebanks around the world to access greater genetic resources by implementing the international treaty of plant and genetic resources for food and agriculture. Networking is vital to the implementation of the global Musa conservation and use strategy; both for sharing out the multidisciplinary characterization and for reaching consensus on joint actions to expand the coverage of collections, and to rationalize and exchange them. This paper will describe and analyze how a genetic resource network such as MusaNet can be built and boost the Musa research community to share and use sustainably Musa genetic resources.
Somatic Embryogenesis from Cell Suspension Culture of Banana Cultivar ‘Cau Man’

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Keywords: Auxin, highly proliferating meristem culture, C.H.P., Musa, somatic embryogenesis

A highly-proliferating meristem-culture was initiated on C.H.P medium containing 0.17 mg/L IAA, 2.5 mg/L BA and 1 mg/L zeatin. A cell suspension from this highly-proliferating meristem-culture was cultured in liquid Ma2 medium supplemented with 35 g/L of sucrose, 1.2 mg/L of 2,4-D, 0.5 mg/L zeatin and 15 mg/L ascorbic acid. Based on histological changes, three stages in the process of somatic embryogenesis were observed: (1) the initiation stage - embryogenic cells were initiated from meristem culture in the presence of 1.2 mg/L 2,4-D and 0.5 mg/L zeatin; (2) the evolution stage - the somatic embryos were developed from a cell suspension at initial cell density of 15 µl/ml SCV (settled cell volume) in a medium containing 0.1 mg/L kinetin, 0.2 mg/L 2-iP, and 0.05 mg/L zeatin; and (3) the germinating stage - somatic embryos at the volcanic stage were germinated in a medium containing 1 mg/L zeatin and 1.5 mg/L IAA. Zeatin treatment increased the number of mitochondria observed under T.E.M. IAA and zeatin levels of the embryos were determined by HPLC (High Performance Liquid Chromatography). The level of IAA increased at the globular embryo stage. Treatments of 1 mg/L TIBA (2,3,5-tri-iodobenzoic acid), an inhibitor of auxin polar transport, at different stages of embryo development has shown that auxin plays a role in determining the position of embryo organs as well as their development. The role of the combination of auxin and cytokinin in somatic embryogenesis will be discussed.
Influence of Initial Cell Density, Culture Media and Temporary Immersion System on the Cell Differentiation and Plant Regeneration of Banana from Cell Suspension Culture

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Keywords: Musa, somatic embryogenesis, micropropagation, temporary immersion bioreactor

High production costs generally limit the commercial use of in vitro micropropagation. Using liquid media is considered to be the ideal solution for automation and reducing production costs. However, depending on the variety, this process can show different levels of difficulty, and so adaptations in protocols are needed. In this study, experiments on cell differentiation and plant regeneration were carried out from banana cell suspension culture by evaluating the initial cell density, culture media and temporary immersion systems. For that, a sequence of three experiments was performed. The first one evaluated the effects of cell density (0.5; 1 and 2 ml - settled cell volume), culture media (M1: 1/2MS, 100 mg/L ascorbic acid, 100 mg/L L-proline, 30 g/L sucrose and 10 µM 2iP; M2: MS, 30 g/L sucrose, 2,2 µM BA and 11,4 µM IAA) and period of cells differentiation (40 and 130 days). The second one analyzed the effect of propagules size differentiated in liquid media (approx. 2.5; 5 and 10 mm diameter) on somatic embryo formation or plant regeneration. Finally, a third experiment analyzed the effects of culture systems with filter-paper-covered mediums and temporary immersion systems on propagules differentiation or plant regeneration. The results showed that no differences were found between both differentiation media, and the best cell densities for differentiation were 1 ml and 2 ml/30 ml medium, while dilutions of 2 ml/30 ml medium increased cell oxidation. Extending the period in differentiation medium from 40 to 130 days was important to produce larger numbers of uniform embryogenic propagules with 10 mm diameter, which can be used in temporary immersion systems (bioreactors) for embryo and plant regeneration. Considering all regeneration systems, the semi-solid regeneration medium covered by filter paper significantly increased somatic embryo differentiation and plants regeneration.
Cell Suspension from the Banana Cultivar ‘Tropical’ (AAAB)

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Keywords: Growth curve, tissue culture, \textit{Musa} spp.

‘Tropical’ (AAAB) is a banana hybrid generated at Embrapa, derived from a cross between ‘Yangambi No. 2’ (AAB) and ‘M53’ (AA), which is similar to ‘Silk’ for most of its features, such as development and yield. ‘Tropical’ is resistant to Sigatoka leaf spot and tolerant to Fusarium wilt. Cell suspension cultures with a high regeneration capacity have been used in unconventional breeding for mutation induction, genetic transformation, isolation and protoplast fusion, and chromosome doubling. Somatic embryos induced by the indirect method were transferred to liquid medium composed of Murashige and Skoog (MS) salts and vitamins supplemented with 1 mg/L 2,4-D, 100 mg/L glutamine, 1 mg/L biotin, 10 mg/L ascorbic acid and 44.5 g/L sucrose. The culture was kept in the dark under agitation (120 rpm) at 27 ± 2°C. The established cell suspension consisted of clusters of yellowish colour and fine grain. In order to monitor the growth of the cell suspension, the settled cell volumes in graduated tubes were measured at 3-day intervals during 18 days of cultivation. The onset of growth occurred after 6 days of culture, and the cells continued to multiply reaching a total volume of cells almost doubled in comparison to the initial 18 days after the beginning of the cultivation.

New Approaches on Banana Plantlets Production in a Temporary Immersion System: The Role of Sucrose Reduction at the Rooting Stage

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Keywords: Temporary immersion bioreactor, micropropagation, costs

Bioreactors provide a rapid and efficient plant propagation system for many agricultural and forestry species, utilizing liquid media to avoid intensive manual handling. Large-scale liquid cultures have been used for micropropagation...
through organogenesis or somatic embryogenesis pathways. In this work, some culture parameters affecting the efficiency of the temporary immersion system bioreactor were investigated. Two different sucrose concentrations (0% and 3%) were added to the culture medium at the rooting stage and after two multiplication subcultures in a temporary immersion system. The treatment also included semi-solid medium, and two cultivars ['Maravilha' (AAAB) and 'Prata' (AAB)] were evaluated. Successive subcultures (35 days per subculture) for multiplication followed by one subculture for elongation and rooting showed that sucrose reduction can be an alternative to banana plantlet production in a temporary immersion system. The multiplication rate between 0% or 3% sucrose did not differ and reached up to 2.4 plantlets per initial shoot, besides improving plant survival in the greenhouse.

Identification of Somatic Embryo Development-Related Genes in Banana Using Suppression Subtractive Hybridization

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The objective of this study was to isolate and identify somatic embryo development-related genes from wild banana (Musa itinerans Cheesm.). A subtracted cDNA library was constructed with embryogenic cell suspensions (ECS) of the wild banana by using Suppression Subtractive Hybridization (SSH). The ECSs subcultured in a cell-multiplication medium were harvested as control materials, and the ECSs subcultured in an embryo-development medium were harvested as the treated materials. Positive clones were randomly selected and sequenced from the SSH-cDNA library. After the removal of duplicates and sequences of low quality, 62 high-quality sequences were obtained. According to BLAST screening and functional annotation, the results revealed that 46 ESTs have high homology with known genes in GenBank, with 12 non-homologous sequences found, presumably being new genes. The differentially expressed genes are involved in primary metabolism, protein binding, transport, cell differentiation and other functions and processes. Among these ESTs, TPD1, heat shock proteins, Zinc finger protein and cell-wall hydroxyproline-rich glycoprotein are probably related to embryo development of banana. The SSH cDNA library can be further used for gene cloning and identification of development-related genes in banana.
Somatic Embryogenesis and Genetic Stability of Regenerated Plants of Banana Cultivars

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Keywords: SSR, growth regulators, \textit{Musa} spp., somatic embryos

Immature male flowers were isolated of ‘Tropical’ (AAAB) and ‘Grande Naine’ (AAA) cultivars of banana and cultivated in semi-solid Murashige and Skoog (MS) culture medium with 3\% sucrose, 1 mg/L IAA, 4 mg/L 2,4-D and 1 mg/L NAA, and glutamine (0, 50, 100, 150 and 200 mg/L). After 4 months of cultivation in the dark, embryogenic mass containing somatic embryos was transferred to liquid MS medium supplemented with 1 mg/L 2,4-D, 100 mg/L glutamine, 1 mg/L biotin, 10 mg/L ascorbic acid and 44.5 g/L sucrose. Cultures were kept in the dark, under agitation (120 rpm) and subcultured every 10 days. The density of cells in suspension was adjusted to 5\% of the settled cell volume. One ml of the new suspension from each cultivar was placed under MS culture medium with 30 g/L sucrose, 7 g/L agar and five different concentrations of the BAP and IAA regulators: (0.0 and 0.0; 0.2 and 0.1; 0.4 and 0.3; 0.6 and 0.5; 0.8 and 0.7 mg/L, respectively). After 1 month, the formation of embryos was observed. Afterwards these were individualized and transferred to fresh medium for germination and plant regeneration. The cultivars responded differently to the doses of glutamine in the induction culture medium: ‘Grande Naine’ formed somatic embryos in the glutamine-free medium and ‘Tropical’ formed somatic embryos in the presence of glutamine. For the regeneration stage, ‘Grande Naine’ presented the best results regarding embryo formation in the culture medium without growth regulators, whereas ‘Tropical’ presented a greater number of regenerated plants in this same medium. Regenerated plants were acclimatized in a greenhouse. In order to evaluate the genetic stability, 11 SSR primers were tested in 18 plants of each cultivar per treatment. No genetic variation was observed using the microsatellite markers tested.
The Effect of Gamma-Ray Irradiation on Somatic Embryogenesis in Cavendish (AAA) Banana

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Keywords: γ irradiation

The production of banana (Musa spp.) is seriously threatened by pests and diseases, such as Fusarium wilt (Fusarium oxysporum f. sp. cubense). High efficiency of somatic embryogenesis is the basis of banana improvement through biotechnological techniques. However, banana is extremely recalcitrant in embryogenic response. In the present study, immature male flowers from a few γ-ray irradiated Cavendish cultivars (AAA) were selected as explants for callus induction, followed by establishment of embryogenic cell suspension (ECS). The effect of γ-ray irradiation on plant regeneration capacity of ECS was also studied. The results showed that γ-ray irradiation at doses from 20 to 80 Gy could significantly increase embryogenic callus induction frequency. After 3 months of selection and subculture, homogenized ECS with high regeneration capacities were obtained. Similarly, γ-ray irradiation at doses from 20 to 80 Gy also could significantly increase the plant regeneration capacity of the ECS, which suggesting that γ-ray irradiation at low doses could stimulate somatic embryogenesis in banana. In addition, a few potential dwarf mutants of ‘Yueyoukang 1’, a cultivar highly resistant to Fusarium wilt, were obtained.

Development of In Vitro Banana Genotypes

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Keywords: Musa spp., micropropagation, fruticulture

Banana and plantain are among the most important food crops worldwide and are cultivated in 80 tropical countries, mainly by small farmers. The quality of planting materials is extremely important, because it is related to uniformity, early yield, plant vigour, health and productivity of the crop. The aim of this
study was to observe the development of some banana genotypes in vitro under different culture media. This work was conducted at the Laboratory of Tissue Culture, Department of Agriculture, Federal University of Lavras. The genotypes of bananas used were: ‘Tropical’, ‘FHIA-01’, ‘Caipira’, ‘Princesa’ and ‘PA-4244’, supplied by Embrapa Cassava and Tropical Fruits. Apical buds with the underlying portion of the rhizome, about 2 cm long were inoculated in three media: MS (Murashige & Skoog, 1962), BDS (Dunstan & Short, 1977) and WPM [(Wood Plant Medium) Lloyd & McCown, 1980]. Each treatment consisted of four replicates, and four explants per pot. After 50 days, plant height, leaf number, root number, root length, mass of fresh and dry matter were evaluated. The data were analyzed with the R Development Core Team (2009), by analysis of variance and multiple comparison test of Tukey with average nominal level of significance of 5%. For the cultivar factor, all variables had significant effects. The factor for the medium showed no significant effect on leaf number. The interaction between the factors cultivar x medium showed a significant effect only for the root feature fresh matter. The WPM culture medium was inferior to MS and BDS with respect to all the phenotypic characteristics studied. Thus, the culture medium WPM is not recommended for the development of genotypes used in this work. Genotypes ‘FHIA-01’ and ‘Princesa’ presented the best performance for the culture media MS and BDS with respect to phenotypic characteristics studied. Each genotype studied showed a different response in each medium.

Micropropagation of Ornamental Banana Hybrids

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Key words: Multiplication rate, Musa spp., tissue culture

Banana plants are recognized worldwide as one of the most beautiful ornamentals. Several ornamental banana hybrids have been generated at Embrapa Cassava and Fruits. In order to validate commercial cultivation of any hybrid, a large number of plants is necessary. Data obtained from micropropagation become relevant, since the cultivation of ornamental fruits is an expanding market. The objective of this study was to evaluate the in vitro morphogenetic response of three ornamental banana hybrids produced by unprecedented crossover Monyet (Musa acuminata ssp. zebrina) x Royal (Musa ornata x Musa velutina). The shoot tips were sterilized in 70% alcohol
for 5 min followed by immersion in 1.25% sodium hypochlorite with Tween-20 for 20 min and rinsed in sterile water. The explants were inoculated on Murashige and Skoog (MS) medium supplemented with 10 µM 6-benzylaminopurine (BAP), 1 mM indole acetic acid (IAA), 57 µM ascorbic acid, 3% sucrose and 0.2% Phytagel® at pH 6.1. The tubes were kept in the dark for 15 days under controlled conditions. After this period, the shoots were transferred to MS medium with a higher concentration of BAP (100µM) for four subcultures (every 45 days). The regenerated plants were transferred to rooting medium (MS without regulators) and acclimatized under greenhouse conditions. The multiplication rate for hybrids RM09, RM33 and RM38 was 6.27, 5.00 and 2.60 in the second subculture, and 2.68, 2.32 and 5.23, in the third subculture, respectively. In the fourth subculture, rates were lower for the three hybrids. The hybrid RM09 showed a higher multiplication rate than the hybrid RM33 in all subcultures. However, in the third and fourth subculture RM38 hybrid showed a higher rate, thus making clear the difference in the potential propagation of the hybrids. The RM09 was the hybrid with the best potential propagation, making it more commercially viable and therefore the recommended hybrid.

**Pair-Wise Estimation of Dissimilarity between *Musa* Accessions Regenerated under Medium-Term Conditions and Accessions Without *In Vitro* Culture Maintained in the East African *Musa* Field Genebank**

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**Keywords:** Field verification

Forty-seven *Musa* accessions which had been maintained under *in vitro* medium-term conditions (MTS) for more than 10 years at Bioversity’s International Transit Centre (ITC) were verified in the field using the minimum set of descriptors. The aim was to confirm that they were still true-to-type after regeneration. For further monitoring of their genetic base, 35 of these plants were later transferred from their field trial to the regional field genebank in East Africa.
Africa. Twelve of the verification accessions either shared names with accessions in the field genebank or were synonyms that had been collected from various parts of East Africa. The immediate question was whether the ITC accessions and the ones in the regional field collection (with the same names) were ramets and if so how much have the post-MTS accessions changed from the corresponding field accessions? The twelve pairs were surveyed for more than 50 morphological characters to assess the level of similarity between the field (non-MTS) accessions and those originally regenerated after MTS and thereafter transferred to the field collection. Results from the pair-wise estimation of resemblances between the 12 pairs of accessions indicated that the range of values of the correlation (0.75-0.98) and distance (0.04-014) coefficients between the pairs that shared names was smaller than the values between other pairs of accessions. This range was used as a measure to give an assessment standard of the levels of dissimilarity between other pairs of accessions. Results indicated that, on the basis of the standard assessment, several other pairs of accessions were found to be similar, differing only in their quantitative characters; hence more synonyms were worked out. This paper is describing the method used in estimating the dissimilarity levels among accessions that shared names and/or known to be synonyms from the field verification trial to those in the field genebank of east Africa. The value of the method is critically discussed.

Selection of Minimum Descriptors in Banana using Univariate and Multivariate Methods

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Keywords: Selection of descriptors, Musa spp., multivariate analysis

The objective of the present work was to quantify the genetic diversity between banana accessions at Embrapa Cassava and Fruits, Brazil, using a list of morpho-agronomic descriptors, as well as to provide a minimal number of descriptors capable of quantifying the diversity between accessions. The phenotypic characterization was carried out for 77 accessions, evaluated with 92 descriptors. The selection of the quantitative descriptors was carried out by principal components analysis and qualitative descriptors by entropy coefficient. The efficiency of elimination of descriptors was analyzed by a comparative study between the clusters formed, taking into consideration both
all 92 descriptors and only the selected ones. The selected descriptors were analyzed in combined fashion by the Ward-MLM procedure. The Ward-MLM method was used and the combined matrix formed by the Gower algorithm. In regard to the selection carried out for the quantitative and qualitative descriptors, it was possible to reduce the number of descriptors used for characterizing the banana germplasm by 51%. The correlation between the matrices, considering the 92 descriptors and the selected descriptors, was 0.82 showing that the reduction in the number of descriptors did not influence the estimation of the genetic variability between the banana accessions. The genetic diversity analysis by the Ward-MLM method demonstrated similarity between the accessions within the same group. However, between groups, it is possible to suggest the presence of variability for the minimal descriptors used, indicating that these genotypes can be used as parents in banana breeding programs.

Karyotype Analysis of Six A-Genome Banana Cultivars with Different Ploidy (AA or AAA)

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Keywords: Musa spp., chromosome features, karyotype analysis

The comparative analysis of karyotypes in various Musa species and clones contribute to the analysis of the evolution of cultivated clones. However, the analysis of the Musa karyotype is complicated by difficulties in identifying individual chromosomes. By using the method of wall degradation hypotonic, karyotype analysis was performed to investigate the chromosome features of six A-genome banana cultivars differing in ploidy, i.e. AA or AAA group. Results show that the diploid (AA) and triploid (AAA) cultivars had different karyotype characteristics. For example, the karyotype formula and type for ‘Tianbaojiao’ (AAA) is 2n = 3x = 33 = 3M + 27m (3SAT) + 3sm and “1A”, respectively; and for ‘Rose’ (AA) is 2n = 2x = 22 = 2M + 18m (2SAT) + 2sm and “2A”, respectively. The karyotype formula for ‘Pisang Mas’ (AA), ‘Hainan Gongjiao’ (AA), ‘GCTCV-218’ (AAA) and ‘GCTCV-119’ (AAA), is 2n = 2x = 22 = 4M + 16m (SAT) + 2sm, 2n = 2x = 22 = 2M + 18m (SAT) + 2sm, 2n = 3x = 33 = 6M + 15m (3SAT) + 12sm, and 2n = 3x = 33 = 6M + 15m (6SAT) + 12sm (3SAT), respectively. However, all these four cultivars exhibited a karyotype asymmetry of type “2B”. Moreover, we also established the idiogram for the six banana cultivars.
Development of a SCAR Marker for the B Genome of Banana

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**Keywords:** Genomes, breeding

There is wide agreement about the attributes conferred by A and B genomes in interspecific natural or artificial hybrids of *Musa acuminata* and *Musa balbisiana*. It is accepted that parthenocarpy and female sterility arose in diploid acuminata accessions with A genomes. It is also accepted that drought tolerance and fruit characteristics, such as starchiness and acidity, are contributed by the B genome. Banana breeding strategies can utilize the concept of genome substitution to breed cultivars with different characteristics. This breeding strategy has been successfully used to add or replace chromosomes by heterologues in species with fully differentiated genomes, notably in wheat. Consequently it is necessary to tag the A and B genomes of banana as a prerequisite for genome substitution. A previously developed Random Amplification of Polymorphic DNA (RAPD) marker for the B genome is difficult to reproduce and should therefore preferentially be converted into a sequence characterized amplified region (SCAR) marker. The objective of this study was to develop a SCAR marker for the B genome of banana. Following cloning and sequencing of the RAPD marker, a SCAR marker was designed. This 20-bp marker was tested on a range of banana genotypes with different genome compositions (AA, BB, AAB, ABB). Agarose gel electrophoresis showed that the markers are constant with a similar size. The marker was absent in only A genome-containing accessions and in all cases the marker was specific for the B genome-containing accessions.

Quantification of the Genetic Diversity between Improved Banana Diploids Using the Ward-MLM Algorithm


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**Keywords:** Hybrids, microsatellites

The objective of this work was to estimate the genetic diversity between 31 improved banana diploids using simultaneously quantitative and SSR data.
The experiment was carried out in augmented block design with 28 regular treatments and three common treatments. Eighteen agronomic characteristics were measured and 20 SSR primers were used. The agronomic characteristics and the SSR markers were analysed simultaneously by the Ward-MLM procedure, and the Cluster and IML procedures were used to make up the groups of improved diploids. The Ward clustering method was used considering the combined matrix obtained by the Gower algorithm. The correlation between the agronomic characteristics and the canonic variables was obtained graphically using the CANDISC procedure in the SAS software. The dendrogram showed relative similarity between the genotypes of the G1, justified by the genealogies, since the 001016-01 diploid is the female parent of the 091087-01 and 091079-03 hybrids. The same occurred with the 013019-01 and 01318-01 diploids which had the wild malaccensis diploid as their ancestor. In G2, the Calcutta 4 diploid appears in 62% of the genealogies. Another diploid, M53, appears in a frequency greater than 33% in the genealogies. Similar behaviour was also observed in G3, since the 028003-01 diploid is the male parent of the 086079-10 and 042079-06 genotypes. Comparing the groups formed by the Ward-MLM method and the one formed by the canonic variables, greater discriminatory power was observed in the second method since six groups were formed compared with only three by the Ward-MLM method.

Genetic Dissimilarity of Putative Gamma Ray Induced ‘Preciosa’ Banana Mutants using Multivariate Statistical Analysis


Embrapa Cassava and Fruits, Cruz das Almas, Brazil

Keywords: Gamma rays, Ward-MLM, mutation induction

Bananas are among the most important fruit crops worldwide, being cultivated in more than 120 countries, mainly by small-scale producers. However, there is a lack of high-yielding, dwarf banana cultivars presenting good agronomic characteristics. Winds continue to damage a great number of plantations each year leading to lodging of plants and bunch loss. The development of new cultivars through conventional breeding methods is hindered by female sterility and low levels of seed production. The use of mutation induction seems to have great potential for developing new cultivars. The objective of the present work was to evaluate the genetic dissimilarity
among putative ‘Preciosa’ banana mutants generated by gamma-ray irradiation, for morpho-agronomic characteristics and using ISSR markers. Approximately 200 in vitro buds of ‘Preciosa’ were irradiated at the Centro de Energia Nuclear na Agricultura (CENA), University of São Paulo (USP), using $^{60}$Co at a dose of 30 Gy, with rates of 1.322 kGy/h. The 190 selected ‘Preciosa’ irradiated plants and 17 controls were evaluated in two production cycles. For this study, the data used were from the second production cycle for evaluating seven multicategory and 21 quantitative agronomic variables. Morpho-agronomic and molecular data from the second production cycle were submitted to the Ward-MLM statistical algorithm using the CLUSTER and MLM procedure in the SAS statistic software, considering a total of seven multicategoric characteristics, 21 quantitative characteristics and 15 ISSR primers in order to evaluate the genetic variability. The distance between the putative ‘Preciosa’ mutants varied from 0.21 to 0.66 with co-phenetic correlation coefficient of 0.8064. Results show that there is variability that can be explored after the irradiation of ‘Preciosa’ and considered in banana breeding programs aiming to develop dwarf varieties with good agronomic characteristics.

Research in Plant Breeding Programs in Brazil: Main Problems and Solutions

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Keywords: Improved gene, scientific and technological development, public policy

The production of cultivars as crop-plant genetic improvement represents a major service of public research institutions and scientific technological development. Thus, the aim of this study was to diagnose the main problems faced by crop science, plant production, plant breeding and genetics programs, as well as to develop possible solutions. To collect data, we performed a literature search embracing national and international journals found at sites recognized scientifically, using the journal portal capes. Problems are listed by uppercase letters and the corresponding solutions by their corresponding lowercase letters. The main problems identified were: (A) inadequate infrastructure for the current scenario with excessive bureaucracy in the decision-making; (B) limited professional management; (C) lack of
collaborative willingness in university work except as a support to commercial programs; (D) lack of technical staff to monitor agribusiness throughout the production chain; (E) lack of expertise in and access to technology products; (F) a focus on undergraduate and some post-graduate research at the expense of more advanced research; and (G) lack of marketing experience and networks to quantify the value of information and its products. For the problems described above, the following possible solutions are proposed: (a) creation of a parallel infrastructure; (b) increase support for researchers; (c) incubate and seek partners for administration and other related areas; (d) promote potential financial benefits of new technologies; (e) develop flexible contracts; (f) promote a more entrepreneurial culture; (g) use the advice of specialist firms; and (h) promote integration using science journalism. In the light of many solutions, there is a need to implement public policies aimed at scientific and technological development with government agencies and research funders.

**Composition and Content of Carotenoids in Fruits of Selected Banana Varieties**

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**Keywords:** *Musa*, fruit, quality, nutrition

Using HPLC-PDA, we analysed the composition and content of carotenoids in fruits of 13 selected banana varieties, which represent the main cultivars groups Cavendish (AAA) and Pisang Awak (ABB) or have research interests. The pulp of ‘Red’ (AAA) and ‘YN2’ (AAA) exhibits an orange-yellow colour, which may be due to their containing higher total carotenoids content (18.1 and 14.96 μg/g fresh weight), β-carotene (11.82 and 10.68 μg/g fresh weight), β-cryptoxanthin (0.72 and 0.17 μg/g fresh weight) and lutein (2.21 and 0.68 μg/g fresh weight). However, the pink peel colour observed in ‘Red Banana’ may be attributed to its having higher anthocyanins content, since the variance underlying carotenoids content is not distinct between cultivars having yellow and pink peel colour. The Cavendish group (AAA) varieties had the lowest contents in total carotenoids (1.70 μg/g fresh weight), β-carotene (0.73 μg/g fresh weight) and α-carotene (0.33 μg/g fresh weight), and no β-cryptoxanthin was detected in the pulp. It is interesting to find that ‘XMJ’, a Pisang Awak, whose pulp colour is white, close to that of the Cavendish group, however, has been found to contain a certain amount of antheraxanthin (2.03 μg/g fresh weight). It was ten times that found in ‘Red’,
‘YN2’ and the Cavendish group. Furthermore, ‘XMJ’ contains violaxanthin (1.55 µg/g fresh weight) that was not detected in the other varieties. The above results revealed that different Musa germplasm has differing carotenoid profiles, which may have specific research interests regarding nutritional benefits to humans. Further steps are needed to understand the regulation of carotenoid formation during carotenoid-rich banana fruit development and ripening.

Iron and Zinc Content of Bananas in Uganda

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\textbf{Keywords:} Banana breeding

Iron and zinc deficiency affects about 3 billion people worldwide. Iron is an important component in human diets because it regulates enzyme activity and plays a role in the immune system. It is also an important component of human blood. Humans require 10-15 mg of iron per day. Health problems caused by zinc deficiency include anorexia, dwarfism, weak immune system, skin legions, hypogonadism, and diarrhoea. In developing countries, iron and zinc deficiency is widespread because of poor nutrition. A large percentage of the worlds’ population in the tropical and subtropical regions of the world subsists on banana-based diets. Breeding of bananas with enhanced micronutrient content, a technology referred to as biofortification, would complement existing strategies of food fortification and supplementation by offering a sustainable and low-cost way of overcoming mineral deficiencies. The objective of this study was to screen a range of bananas from the germplasm collection in Uganda and assess their iron and zinc content. The sample included 9 East African Highland bananas, 11 accessions from Papua New Guinea, 7 dessert bananas, 4 juice/beer bananas, 8 roasting bananas, 4 FHIA hybrids, ‘Pisang Mas’, \textit{Musa acuminata} ssp. ‘Msahle’ and the hybrid TMB2x 5610. Zinc and iron levels were determined using the atomic absorption spectrophotometer (AAS). The average highest iron content (1.420 mg/100g) was found in the accession ‘Saba’ while the lowest iron content (0.063 mg/100g) was found in ‘Kikundi’. The highest average zinc content (1.219 mg/100g) among the analysed accessions was found in ‘Kikuyu’, while zinc was not detectable in the cultivars ‘Kabucuragyé’ and ‘Grand Naine’. This variability in the chemical composition of bananas will be useful for plant breeders and nutritionists who may wish to select/breed for a combination of desirable characteristics including high micronutrient content.
Morphological Characterization and Fertility of Auto-Tetraploid Bananas Obtained by Chromosome Doubling


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Keywords: Tissue culture, colchicine, orizaline, pollen grains

Banana cultivars of the Cavendish subgroup (AAA) represent over 45% of the banana production worldwide. Conventional breeding through hybridization is inefficient for creating cultivars from the Cavendish subgroup, because of sterility observed in these genotypes. Induction of chromosome doubling is an alternative to generate new AAA triploids resistant to diseases and with good fruit quality. The auto-tetraploid obtained through this technique can be used to generate secondary AAA triploids by crossing it with AA diploids. This study aimed to evaluate auto-tetraploids obtained by chromosome doubling using colchicine and orizaline. Parthenocarpic diploids of *Musa acuminata* (Ouro, Lidi, Thong Dok Mak and NBA 14) were used to obtain the auto-tetraploids. The ploidy of 1200 preselected regenerated plants was determined by flow cytometry and 400 possible auto-tetraploids were identified beside diploids and mixoploids. Fertility was assessed by 2,3,5-triphenyltetrazolium chloride (TTC) staining and *in vitro* germination of pollen grains. Different levels of fertility among the auto-tetraploids were observed. Plants with doubled chromosomes were more vigorous and produced larger fruits than those from the diploid controls.

Pollen Fertility of Tetraploid Banana Cultivars


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Keywords: *Musa acuminata*, in vitro pollen germination, 2,3,5-triphenyltetrazolium chloride

The generation of tetraploid cultivars from triploids has a consequential total or partial restoration of fertility, allowing the occurrence of fruit with
some seeds that are undesirable for the consumer. The objective was to evaluate the viability of pollen grains of twelve tetraploid banana hybrids (AAAB). The identification of integrity of the pollen was verified by the use of acetic carmine and 2,3,5-triphenyltetrazolium chloride (TTC) staining. The ability of pollen-tube growth was evaluated by the germination *in vitro* in three culture media: (M1) 0.03% Ca\(\text{NO}_3\).4\(\text{H}_2\text{O}\), 0.02% Mg\(\text{SO}_4\).7\(\text{H}_2\text{O}\), 0.01% K\(\text{NO}_3\), 0.01% H\(\text{BO}_3\) and 15% sucrose; (M2) 0.03% Ca\(\text{NO}_3\).4\(\text{H}_2\text{O}\), 0.01% K\(\text{NO}_3\), 0.01% H\(\text{BO}_3\) and 10% sucrose; and (M3) 0.015% H\(\text{BO}_3\), 0.045% Ca\(\text{3(PO}_4\)\)\)\) and 25% sucrose. A total of 300 pollen grains per genotype were observed through cytological techniques, and for germination rate evaluation, the average of 1215 pollen grains were inoculated on each medium. Carmine staining indicated a high viability of pollen grains (above 80%), except for the genotypes ‘YB42-17’ and ‘Caprichosa’ that showed 76% and 70% viable pollen grains, respectively. However, *in vitro* germination was below 50% for all genotypes, except for the hybrids ‘YB42-17’ and ‘YB42-47’. Staining provided TTC viability estimated closer to those achieved by *in vitro* germination test and could be recommended for more rapid analysis of pollen viability in banana. After 24 hours of incubation, the medium M1 showed the highest percentage of germination and pollen tube length. Among the genotypes evaluated, ‘YB42-47’ had the highest germination percentage (61.5%) and greater length of the pollen tube (5.0 mm). However, the cultivar ‘Vitoria’ had the lowest percentage of pollen germination (8.2%) in medium M1. Studies on meiosis may assist in understanding the differences observed in the tetraploids tested, since meiotic irregularities can affect the pollen viability.

**Influence of Floral Tissue Extracts on *In Vitro* Pollen Germination and Pollen Tube Growth in Banana**

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**Key words:** *Musa* spp, stigma, ovary, breeding

The genetic breeding of banana through hybridization is limited by the occurrence of sterility in most cultivars resulting in low production or absence of seeds. Studies are needed to better understand the processes involved in banana sterility and to develop strategies to overcome this barrier. The aim of this study was to evaluate the effect of floral extracts of ‘Grande Naine’ (AAA) on the percentage of *in vitro* pollen germination and pollen tube length in bananas. Pollen grains from the 089087-01 diploid were inoculated into media
culture with 15% of sucrose, 0.01% $\text{H}_3\text{BO}_3$, 0.01% $\text{KNO}_3$, 0.03% $\text{Ca(NO}_3)_2\cdot 4\text{H}_2\text{O}$, 0.02% $\text{MgSO}_4\cdot 7\text{H}_2\text{O}$, supplemented with extracts of the stigma and distal portion of the ovary from the female inflorescence of ‘Grande Naine’, solidified with 0.8% agar and pH adjusted to 5.8 or 7.0. Extracts of floral tissue were obtained by maceration in liquid nitrogen and water extraction. The samples were centrifuged and the supernatant was filter-sterilized and diluted in the culture medium in concentration of 0%, 1.25%, 2.5%, 5% and 10%. For the germination percentage, 320 grains per Petri dish were counted and the length of the pollen tubes was measured in 40 pollen grains per plate, with eight replications. Pollen germination and pollen tube length were higher in culture medium containing extracts of the stigma in the concentration of 5% with values of 92.75% and 4.84 mm, respectively, in comparison to the control (37.5% and 3.05 mm, respectively). However, for the concentration of 10%, germination percentage was reduced to 21.88%. The effect of the ovary extract was contrary to that of the stigma. At a concentration of 10%, the germination percentage (67%) and pollen tube growth (4.7 mm) were significantly higher than the control. The results indicate that substances present in the extract of stigma may be related to sterility in ‘Grande Naine’.

Evaluation of Segregating Populations from *Musa acuminata* ssp. *burmannicoides* (Calcutta-4)

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**Keywords:** F$_1$ Hybrid, Kadali, Anaikomban, morphological traits

*Musa acuminata* ssp. *burmannicoides* ‘Calcutta-4’ is widely used in breeding programs as a major contributor of genes towards tolerance to leaf spot and Fusarium wilt. We have used it in generating mapping populations. The male parents involved were ‘Kadali’ and ‘Anaikomban’ (AA). Crosses were made involving 75 flowers of ‘Calcutta-4’ with ‘Kadali’ and 40 seedlings germinated out of 229 seeds. Twenty-four seedlings survived in the field, where as only 11 of them produced flowers and fruits. In the cross between ‘Calcutta-4’ and ‘Anaikomban’, we produced 1061 seeds, and 53 seedlings germinated. Thirty seedlings survived in the field and nine of them produced flowers and fruits. Among the 16 morphological characters observed, majority of the F$_1$ hybrids had small bunches like ‘Calcutta-4’. Hybrids involving ‘Anaikomban’ as the male parent had the highest plant height (192 cm), number of suckers (17), petiole length (46 cm), fruit length (11 cm), fruit weight (51.67 g), bunch
weight (3.2 kg) and total soluble solids (24⁰B). The progenies involving ‘Kadali’ as the male parent showed the highest pseudostem girth (26 cm), number of leaves (7), leaf length (169 cm), leaf breadth (64 cm), bunch length (27 cm), peduncle length (18 cm), number of hands (8), number of fingers (106), and finger girth (3.16 cm). All the F₁ plants morphologically resembled the female parent ‘Calcutta-4’ and showed variability for plant height and fruit quality. Further attempts are being made to increase the population size and to use these F₁s for screening against Fusarium wilt, development of molecular makers and functional genomics.

Polyploidy Induction through Different Concentration of Colchicine in Banana Cultivar ‘Mas’ (Musa AA)

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In the present study, we attempt to develop a novel way for obtaining tetraploid plants through colchicine-induced chromosome doubling in diploid edible banana cultivar ‘Mas’ (AA). Thus, we investigated the effects of dose and time duration of colchicine treatment on different explants, including embryogenic cell suspensions, embryogenic callus and multiple buds. Results showed that all three kinds of explant materials treated by colchicine are relatively sensitive to higher concentration of colchicine. The treatment with a concentration of 0.4% (w/v) colchicine and 48 h of treatment duration has a clear induction effect on multiple buds, resulting in a mortality rate of 45.83% but with 18.64% of the progenies being tetraploids. Using microscope observation, we identified 62 tetraploid seedlings with double chromosome numbers and reduced frequencies but enlarged sizes of the leaf stomata. The presented experiment provides useful information with technical and basic references to polyploid induction/mutation breeding and creation of new germplasm in Musa genetic improvement.
Stomatal Studies and its Relation to Drought Tolerance in *Musa*

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Drought is one of the most important environmental constraints limiting plant growth and productivity. We need to understand the underlying mechanism and to identify genes responsible for drought tolerance. In this study, stomatal density was measured in a number of *Musa* genotypes belonging to different genomic groups. Stomata are microscopic pores present in the plant epidermis that regulate gas exchange between the plant and the atmosphere. They also play a vital role in water use efficiency and drought tolerance. Microscopic observations of stomata and epidermal cells were done for natural hybrids belonging to the AB, AAB, ABB, AAA, AA, BB genome. The stomatal density and LWRC (Leaf Water Retention Capacity) values for natural hybrids negatively correlated with adaxial stomatal density, significant at a value of -0.927. This shows that the lower the stomatal density, the higher the leaf water retention capacity. LWRC values ranged from 40 to 75%. The correlation between abaxial stomatal density and LWRC was -0.420. The adaxial stomatal density values ranged from 7 to 128. The variation in stomatal density was interesting and indicates that stomatal density is an important trait for water use efficiency and drought tolerance.

The Role of Cuticular Wax in Drought Tolerance in *Musa*


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**Keywords:** Biosynthesis

Cuticular wax, a hydrophobic layer present on the aerial parts of plants, helps in reducing the non-stomatal water loss and protects plants from biotic and abiotic stresses. Quantitative analysis of cuticular wax was done using spectrophotometric assay, in the leaves of ‘Calcutta-4’ (*Musa accuminata* ssp. *burmannicoides*) and ‘Bee hee kela’ (*Musa balbisiana*) parents and a set of F<sub>1</sub> hybrids which were chosen based on their LWRC (Leaf Water Retention Capacity).
Capacity) values. GC-MS (Gas Chromatography Mass Spectrometry) analysis of the hexane wax extracts was done to analyse the components of cuticular wax in the same genotypes. The quantitative analysis showed that cuticular wax content positively correlated with LWRC with a value of 0.715. The above results indicate that cuticular wax plays an important role in preventing water loss from the plants. Genes responsible for wax biosynthesis needs to be identified and further characterized and can be used as a tool to improve the plants for drought tolerance.

A Protein Extraction Method Compatible with Proteomic Analysis of the Interaction between Musa acuminata and Mycosphaerella musicola

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Keywords: Biotic stress, Yellow Sigatoka, disease resistance, proteomics

Sigatoka leaf spot, caused by Mycosphaerella musicola, reduces functional leaf area and causes premature fruit ripening. The wild diploid cultivar Musa acuminata ssp. burmannicoides ‘Calcutta-4’ is used as a source of resistance in breeding programs and serves as a model for comparative genomics, functional genomics and candidate resistance gene discovery. In this context, a proteomics study was undertaken in order to identify protein expression in the M. acuminata – M. musicola interaction. Total proteins were extracted from leaf material for ‘Calcutta-4’ (resistant) and Cavendish cultivar ‘Grande Naine’ (AAA, susceptible), both uninoculated and inoculated with M. musicola conidiospores. The extraction methodology was optimized, using acetone to remove leaf pigments, followed by 10% TCA/acetone to remove further pigments and precipitate total proteins, plus a second exposure to 10% TCA/acetone to remove water and precipitate soluble proteins. A solubilization buffer was used to assist in the separation of phases in the extraction with phenol. After dissolving the material, proteins were precipitated in 75% TCA. Isoelectric focusing (1st dimension) was performed using the IEGPhor system, in which proteins are separated by electrophoretic migration in a pH gradient. SDS-PAGE (2nd dimension) was performed to separate proteins by size. Proteomic analyses of this interaction are currently ongoing. Results will provide important information on the profiles of expressed proteins and post-
translational changes during the *Musa*-pathogen interaction, representing a link between genotypic and phenotypic information. Proteomic analysis, in overlap with the transcriptome information generated by NGS pyrosequencing, will contribute to genetic improvement of *Musa*.

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**Characterization of EST-Derived SSR Markers in *Musa acuminata***

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Banana (*Musa* spp.) is one of the world’s most important monocotyledonous crops. Many cultivars are susceptible to fungal diseases such as black leaf streak and Sigatoka leaf spot, which attack leaf tissues and can cause production losses of up to 100%. Genetic breeding programs have been based upon selection of resistant individuals. The objectives of this study were to characterize 303 SSR markers derived from cDNA libraries prepared from *Musa acuminata* leaf materials contrasting in resistance, and *in vitro* infected with *Mycosphaerella fijiensis* (the causal agent of black leaf streak), and to identify potential association with Sigatoka resistance. A total of 170 primer pairs were designed from the Cavendish subgroup, cultivar ‘Grande Naine’ (AAA) (susceptible), together with 133 pairs in *Musa acuminate* ssp. *burmannicoides* ‘Calcutta 4’ (resistant). Marker polymorphism was initially examined using four DNA bulks obtained from 20 A-genome diploid individuals contrasting in resistance to black leaf streak and Sigatoka leaf spot. Primer annealing temperatures were optimized between 50-60°C and polymorphism examined on 4% polyacrylamide gels with silver staining. Currently, 25% of the loci display polymorphism, 25% display monomorphism, 34% show problems in amplification and the other 16% are in the process of characterization. Polymorphic markers were tested against individualized bulks in order to determine if members displayed common alleles. Data were analysed using the software Powermaker 3.25. A total of between two and seven alleles per locus were observed, with an average of four. From an expected heterozygosity (*He*) of 0.55, an observed heterozygosity (*Ho*) of 0.48 was observed, with a PIC value of 0.50. Polymorphic markers will be important in genotyping and in genetic map construction for *Musa* segregating populations.
Validation of EST Data Obtained for Banana Cultivar ‘Manoranjitham’ Challenged by the Eumusa Leaf Spot Pathogen (*Mycosphaerella eumusae*)

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**Keywords:** Sigatoka, SSH, EST library, Real Time PCR

Eumusa leaf spot, caused by *Mycosphaerella eumusae*, is one of the major biotic stresses that affect banana production across a large number of commercial cultivars. At NRCB, a large number of banana accessions have been screened and resistance has been identified across various genomes. Two accessions, ‘Grand Naine’ and ‘Manoranjitham’, with same AAA genetic background but contrasting reaction to *M. eumusae*, were selected for the study. Identification of resistant genes for *M. eumusae* from the resistant ‘Manoranjitham’ was attempted through an SSH approach. A library containing 850 ESTs was obtained and assembled into 297 singletons and 58 contigs by CAP3 analysis. All 355 unigenes were annotated using BLAST search and were categorized into 13 major groups (Antibiotic, Development/Storage /Dormancy, Miscellaneous, Defense Mechanism, RNA Processing and Modification, Transcription, Post-Translational Modification, Protein Turnover and Chaperons, Energy Production and Conversion, Metabolism, Cellular Redox State, Hypothetical Protein and Cell Cycle Control) with 63 subgroups. Validation experiments were carried out using Roche Light Cycler 480 with a SyBrGreen format for four groups, namely Metabolism, Cellular Redox State, Defense and Miscellaneous. Degenerate oligos were designed for the ESTs exhibiting highest query coverage and E-value paradox and real time PCR assays were carried out. The results revealed that the expression levels were upregulating in all four groups with an exception for the EST coding for putative trpB gene of the metabolism group. Further expression studies on other subgroup members are in progress.
Assessment of RNA Interference-Mediated Gene Silencing in Banana Using a Transgene

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Keywords: RNA duplexes, embryogenic cell suspension, GUS silencing

RNA interference (RNAi) technique is a powerful tool to suppress gene expression and to discover functions of eukaryotic genes. Stable RNA silencing by vector-based small interference (siRNA) expression has been achieved in animals and many plant species, but has not been demonstrated in banana (*Musa* spp.). In this study, using the β-glucuronidase (GUS) encoding *gusA* reporter gene, we aim to assess the feasibility of RNAi in banana by siRNA duplexes. Three different silencing constructs that generate hairpin RNA of 300 nt, 26 nt and 19 nt duplex RNA targeting different sites of the *gusA* gene were transferred into stably GUS-expressing embryogenic cell suspensions (ECS). Up to 1 month after transformation, GUS activity was not significantly down-regulated, which might be explained by the relatively low transformation frequency. Therefore, transgenic lines are under regeneration to detect GUS silencing by these RNA duplexes in regenerated plants. Alternatively, these silencing constructs were co-transformed with a *gusA* containing vector into ECS. Within 1 week after co-transformation, GUS activity was suppressed by the 19 nt and 300 nt RNA duplexes. Co-transformed plants are also produced for GUS silencing assessment. Preliminary results of silencing at RNA and enzyme level in *in vitro* plants by both approaches will be presented. Taken together, the results of GUS silencing in ECS by RNAi are promising and warrant further studies of (trans)gene silencing in banana with the final aim to functionally characterize agronomically interesting genes.
Cloning, Characterization and Over-Expression of a Nucleoside-Diphosphate Kinase (NDPK) Gene from Banana for Developing Abiotic Stress Tolerance

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Bananas constitute one of the most important fruit crops worldwide. Exposure to adverse environmental conditions such as drought, salinity and temperature extremes results in marked physiological and biochemical changes in plants, along with significant alterations in their gene-expression profiles. Nucleoside-diphosphate kinases (NDPKs) are housekeeping enzymes which maintain the intracellular levels of all (d)NTPs (except ATP) in higher organisms. NDPKs play significant roles in stress-response signal-transduction pathways in plants. Over-expression of AtNDPK2 led to increased tolerance to abiotic stress in Arabidopsis, sweet-potato, potato and poplar. Abiotic stresses, chiefly drought and suboptimal temperatures, cause major yield losses in banana cultivation thereby necessitating the development of lines tolerant to abiotic stress. Development of such lines is difficult using conventional breeding methods as most of the edible bananas are triploids. Over-expression of the NDP kinase gene constitutes one of the feasible strategies for obtaining abiotic stress-tolerant banana lines. In this context, an NDP kinase gene was identified using in silico approaches from banana EST database. This NDP kinase (putatively titled MusaNDPK-1) is a 148 amino-acid protein containing a 130 amino-acid long NDPK-1 domain. Sequence-similarity and signal-peptide scan searches revealed that MusaNDPK-1 is probably a cytosolic protein. Real-time PCR analysis indicated that its expression in banana plantlets was induced by drought, salt, heat and oxidative stress. MusaNDPK-1 cDNA sequence was cloned in pCAMBIA-1301 plant binary vectors in an expression-cassette containing Zea mays polyubiquitin promoter and nos 3’ UTR. This binary vector was then used to transform banana embryogenic cell suspension cultures using Agrobacterium tumefaciens. In addition, two other NDP kinase genes were identified in the banana EST database, with efforts underway to amplify and characterize these genes. Further results on these and related aspects will be presented.
Determination of the LD50 of Mutagens and Evaluation of the Mutants against Fusarium Wilt (Race 1)

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Key words: Mutation, improvement, banana

Banana is an internationally important food fruit crop which is grown in tropical and subtropical regions of the world. It provides the food and nutritional security for many of the developing economies. However, bananas are increasingly threatened by a series of biotic and abiotic stresses emphasizing the need for incorporation of genetic stress resistance, either through conventional or non-conventional breeding methods. ‘Rasthali’ (AAB, Silk) is a popular cultivar urgently needing transfer of Fusarium wilt resistance genes. Such transfer through classical breeding is quite tedious because of its triploidy and male and female sterility. In this context, induced mutagenesis combined with toxin-based screening serves as the potential tool for the development of a wilt-resistant ‘Rasthali’ derivative. Therefore, attempts were made in the present investigation to determine the LD50 of physical and chemical mutagens for proliferating buds of ‘Rasthali’. The proliferating buds obtained after three subcultures were either irradiated with gamma rays at varying doses (10, 15, 20 and 25 Gy) or treated with chemical mutagens at various concentrations and for various time durations prior to their initiation in normal Murashige and Skoog (MS) medium containing 4.0 mg/L BA, 2% phytage and 3% sucrose. The LD50 was determined based on 50% fresh-weight gain as compared to control. LD50 for gamma rays was found to be 20 Gy, 0.6% for ½ hr in EMS, 0.01% for 1/2 hr in sodium azide and 4mM for 2 hr in diethyl sulphate. The mutated buds which gave rise to multiple shoots were further inoculated in MS medium containing 0.025 mM fusaric acid and 3% culture filtrate for in vitro screening against Fusarium wilt. After preliminary screening using PCR-based markers, one set of putative mutants have been selected for in vivo screening (pot culture) and the other taken for field evaluation.
Certification of Banana Cultivar ‘CIENBTA-03’, with Resistance to Mycosphaerella Leaf Spot, for Seed Production and Marketing in the Central Region of Venezuela

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The banana cultivar ‘CIENBTA-03’ (AAAA), resistant to black leaf streak and Sigatoka leaf spot, was obtained through adventitious shoot induction with 15 mg/L BA from in vitro plants of ‘Williams’ (AAA), a cultivar susceptible to Sigatoka disease. This research was carried out in the Biotechnology Laboratory of the Science Faculty at the Universidad Central de Venezuela. The resistant cultivar was initially selected in 1996 from a field with high Sigatoka leaf spot disease pressure. Since then, several investigators from our lab have demonstrated that this cultivar is also resistant to black leaf streak. We also reported morphological, biochemical, cytogenetic and genetics differences, between ‘CIENBTA-03’ and its parental ‘Williams’. In addition, a comparison of characteristics of fruits from ‘CIENBTA-03’ and ‘Williams’ revealed that ‘CIENBTA-03’ shows better sensory characteristics than ‘Williams’. In 2005, we also demonstrated the genetic stability of ‘CIENBTA-03’ plants obtained through in vitro multiplication via apical shoot culture, and the stability of resistance to black leaf streak in those plants, through five cycles of micropropagation. In the present work, we reveal the field performance results of six banana cultivars (‘Yangambi Km5’, ‘Grande Naine’, ‘Pisang Mas’, ‘Williams’, ‘FHIA-02’, ‘CIENBTA-03’) and ‘Harton’ plantain. The agronomic experiments were conducted during two production cycles in three different locations in Venezuela: a) Experimental station “Saman Mocho”, Faculty of Agronomy, UCV, Carabobo State; b) Plot land in “Esmeralda, in Ocumare de la Costa”, Aragua State; and c) Plot land in Santa Barbara of Zulia, South of the Maracaibo lake, State of Zulia. The infection indexes of the ‘CIENBTA-03’ plants were similar to those of the resistant reference cultivar ‘Yangambi Km5’, in the plots of Aragua and Carabobo. Therefore, it has been accredited for the production of certified seeds.
Keynote: Banana Fruit and Cooking Banana Physicochemical and Functional Differentiation during Ripening: A Key Study for Understanding Consumer Preferences

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**Keywords:** *Musa* sp., diversity, acceptability, quality, objective criteria

The commercial success of a given dessert or cooking banana variety is based on the acceptability by the stakeholders: consumers and/or processors of the food chain. Unsuccessful commercial attempts for varietal adoption or the use of new processes can be due to the low consideration given to the consumer preferences (socio-economics of food) during varietal development or processing. Banana may be consumed raw at full ripeness for the dessert types or after being cooked at various stages of ripeness for the cooking types, and can also be fermented at full ripeness for brewing or bioethanol production. The study presents the collaborative investigations carried out at CIRAD and CIAT aiming at differentiating varieties, genetic groups (haploidy) or consumption groups (dessert and cooking). The statistical tests carried out help to validate the most suitable consumption mode for an unknown variety at various stages of ripeness according to the following criteria: i) Morphology: bunch shape and weight, finger size, diameter and weight, and pulp-to-peel ratio; ii) Physicochemical composition of the pulp: dry matter content, texture, pH, titratable acidity, ash, mineral content, soluble solids, starch, sugar, organic...
acid content and flavor; and iii) Functional properties of starch and flour by rapid viscosity analysis (RVA) and differential scanning calorimetry (DSC): pasting temperature, cooking ability, peak viscosity, onset temperature, gelatinization enthalpy and amylose content. Based on socio-economic surveys, the methods used for *Musa* screening helped to differentiate and/or select suitable varieties based on the prediction of their respective adoption by the stakeholders and users. The methods applied will contribute to the improvement of the breeding strategies while favouring the selection of optimally coupled variety and process for agro-industrial uses.

**Keynote: Alternative Uses of Banana and Plantains: Challenges and Opportunities**

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**Keywords:** *Musa* spp., innovation, ornamental plants

Almost every part of banana and plantain plants has some economic or medicinal use. Besides use as a dessert or cooking fruit, the banana plant can be used for many other purposes. The fibres obtained from the pseudostem can be utilized in the paper and pulp industry as biodegradable binding ropes and in the textile industry. The fruit peel is used in dyeing, and as a base material for alcohol production, biogas production and pectin extraction. The flowers and the central portion of the buds are usually cooked as vegetables. Banana roots, flowers, stem and leaves can be used in the pharmaceutical industry. Another alternative use is as ornamental plants. The banana germplasm has been primarily used in breeding programs for generating new cultivars as food. In order to diversify and expand the use of the variability in germplasm bank of Embrapa Cassava and Fruits, accessions with ornamental potential have been selected to obtain new hybrids for the following uses: as landscape plants, as potted plants, and for cut-flowers or ornamental mini-fruits. This paper summarises the main banana and plantain uses, paying special attention to ornamental purposes. The main challenges and opportunities for innovations, creating new products and reaching new market niches are also addressed.
Keynote: Just Green Bananas: Towards Full Sustainability of the Export Banana Trade

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Keywords: Environment, ethical trade, certification, standards, consumers, marketing, retail

Bananas are an important food item for European and American consumers. It is generally the best-selling fruit item in the typical European supermarket. Over the past years, the concerns of consumers and industrial actors in the banana value-chain about food safety and sustainability issues have grown tremendously. Some concerns directly affect the confidence of the shopping public, such as pesticide use and residues in fruit. Other concerns affect the opinion of the general public, such as working conditions on plantations and the environmental impacts of banana production and transport. Though sustainability is high on the agenda of the public and policy makers, it does not appear in the top three buying motives of most consumer segments. Price, quality and taste are the most important buying motives, and these do not match logically with sustainability. Only a group of socially and environmentally aware customers intentionally buy sustainable products. For this group, retailers offer sustainable product categories, like organic and Fairtrade bananas. These well-known and visible sustainability labels only have captured a relatively small percentage of the market. A market breakthrough for Fairtrade has only been reached when Fairtrade bananas are offered by the retailers at the same price as conventional bananas. This shows how people in their role as citizens may find sustainability important, but as consumers attach a higher value to price, quality and appearance. It also shows that the retail industry has a key responsibility in guiding the mainstream consumer towards sustainable choices; consumers on their own cannot drive this agenda. The effects of banana retail pricing on sustainability are discussed. Sustainability should encompass the whole range of bananas, and not just some high-price, niche categories. In the same way, sustainability should not be limited to what happens on farm, but concerns the whole supply chain, including impacts of farm input manufacture and supply, farm management, packaging, shipping, distribution, waste, etc. The leaders in the value chain, especially retailers and importers, can most influence other actors regarding such an agenda. We also see a shift from thinking of sustainability in terms of immediate local impacts of a banana crop (e.g. farm pesticide, farm labour) to global impacts (e.g. on
world climate and water resources). Sustainability comprises social, environmental, ecological and economic aspects. The industry has responded by introducing voluntary business-to-business standards such as SA8000, Ethical Trading Initiative, business-to-consumer standards, such as Fairtrade, organic and Rainforest Alliance, or sustainability management systems, notably ISO 14001. These standards were usually derived from other commodities and have different focuses. The adequacy for these standards to measure and improve sustainability for the banana chain needs to be assessed. Efficient water and energy use and the emission of carbon dioxide along the chain can be estimated using life-cycle analyses, with standardized protocols. The monoculture system of just a single banana variety for export (Cavendish) provides efficient production in large volumes, and explains its dominant position in the shop. The narrow genetic basis also favours the incidence of pests and diseases. It is interesting whether there is a commercial case to be made for different banana varieties, either newly bred or existing ones with yet unknown commercial appeal. For this to be successful, fruit qualities of such varieties need to match with consumer interest, retailer policies and logistics and be affordable. Bananas are not the only bulk crop with sustainability issues to be addressed. Other crops, such as soy, cotton and sugar cane, show how best-practice sustainable behaviour in other commodity production systems and supply chains can be codified. Based on this analysis, we propose a sustainability agenda for the future. There is a need for a comprehensive “green banana” standard or at least a broadly supported view of what a sustainable banana is. The content of this definition is just as important as the process by which it is being shaped and the stakeholders who participate. Secondly, we also propose research efforts to be directed towards the sustainability needs of the industry and to be accessible for all industry actors, big and small.

Using Multivariate Analysis in Evaluating Improved Banana Varieties

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Keywords: Physico-chemical, hybrids, cluster analysis

Black leaf streak and Sigatoka leaf spot affect several banana-producing regions in the world. The aim of this study was to evaluate physical and physico-chemical properties of 15 banana hybrids with resistance to these
diseases, developed by Embrapa Cassava and Tropical Fruits, along with commercial varieties ‘Grand Naine’ (AAA), ‘Pacovan’ (AAB) and ‘Prata Anã’ (AAB). Three bunches of each genotype were harvested in the experimental field of EBDA in Conceição do Almeida, BA where each plant was a repetition. The fruits were evaluated in ripening stage 6. Physical characterization included: yield (%), chroma (C*), hue (h*), number of bunches, number of fruits, bunch weight (kg), pedicel length (cm), pedicel diameter (cm), stem weight (kg), fruit length (cm), fruit diameter (cm), skin thickness (mm) and firmness (N). The physico-chemical parameters were: total carotenoids (µg/g), reducing sugars (% glucose), total sugar (% glucose), acidity (% malic acid), soluble solids (%Brix), ash (%), moisture (%), protein (%) and starch (%). The data were subjected to multivariate analysis of grouping, using the method UPGA and Principal Component Analysis (PCA) from the correlation matrix, using the program Statistica. Cluster analysis showed the formation of three distinct groups. The first was formed by ‘Ambrósia’, ‘Bucaneiro’, ‘Calipso’, ‘FHIA-02’, ‘FHIA-18’, ‘Maravilha’, ‘Grand Naine’ and ‘Caipira’; the second was formed by ‘Garantida’, ‘Preciosa’, ‘Japira’, ‘PV 4253’, ‘PV 7934’, ‘PrataAnã’, ‘Pacovan’, ‘Tropical’ and ‘PA 4244’; the third group was formed by ‘Thap Maeo’ (a kind of Mysore). This variety has physical and physico-chemical properties very different from the other varieties. The results were confirmed by PCA, where the first two components explained 47% of data variation. The different physical and physico-chemical properties presented by the varieties were mainly influenced by genotypic characteristics, considering that the hybrids were grown under the same climate and conditions of irrigation and fertilization.

Varieties Resistant to Black Leaf Streak with the Potential for Jams Processing


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Keywords: Physico-chemical composition, raw material, multivariate analysis, agroindustry

Varieties used in the banana jams agro-industry mostly belong to the Cavendish subgroup and are highly susceptible to black leaf streak. The
objective of this study was to compare the physico-chemical and sensory characteristics of banana jams processed with varieties resistant to black leaf streak to those made with the traditional variety ‘Grande Naine’. The following variables were evaluated: pH, total tritratable acidity, soluble solids, total solids, yield, total sugars, reducing- and non-reducing sugars, humidity, water activity, firmness, adhesiveness and colour. A multi-sample difference test was used for the sensory analysis. There were no differences among the treatments for total soluble solids, total solids, humidity, brightness and yellow intensity. The total tritratable acidity and reducing sugars were superior in the products obtained with resistant varieties. The non-reducing sugars in the products produced with ‘Bucaneiro’, ‘Calipso’, ‘Thap Maoe’, ‘FHIA-18’ and ‘FHIA-02’ were inferior compared to ‘Grand Naine’. The firmness of the products from ‘Thap Maoe’, ‘Caipira’ and ‘FHIA-18’ was superior to the ‘Grand Naine’ product. The highest adhesiveness was found in product from ‘Caipira’ and the highest red intensity in ‘Thap Maoe’. The sugars were the variables responsible for the great diversity. In the cluster analysis, the product made with ‘Grande Naine’ was close to the product from ‘Caipira’, ‘Ambrosia’, ‘Calipso’ and ‘Bucaneiro’. ‘Thap Maoe’ was the most distant variety in relation to the traditional variety. The tasting-panel judges did not notice any significant differences in flavour from the jams produced with ‘Bucaneiro’, ‘Calipso’, ‘Thap Maoe’ and ‘FHIA-02’ in comparison to the control sample. ‘FHIA-18’ presented a performance slightly superior to the traditional variety. Based on the results, some black leaf streak-resistant banana varieties can be recommended for the production of jams with the same or superior quality as ‘Grande Naine’.

The Banana Market in Ethiopia: Status and Agenda for Change

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Keywords: Transaction costs, marketing, cooperatives

Product diversification and linking smallholders to both domestic and international markets (by enabling smallholders to produce marketable output) is becoming a focus of development strategies in most Sub-Saharan African countries, including Ethiopia. Encouraged by exports promotion and diversification needs, production and export of banana in Ethiopia, for instance, has shown a tremendous growth in the last 15 years. Banana production increased from 80,000 tonnes in 1993 to 215,000 tonnes in 2005, and area
harvested increased from 10,000 hectares to about 29,000 hectares for the corresponding period (FAOSTAT, 2008). Banana exports have also increased significantly in the last decade. However, banana production and marketing in the major producing areas remains predominantly traditional. The marketing system can essentially be regarded as indigenous and traditional, with strong cultural and personal control. This study discusses the banana market structure and major marketing bottlenecks that hamper the sector in Ethiopia, by collecting household data from 203 banana producers. The results reveal the market is characterized by high transaction costs related to information and search, negotiations and bargaining, as well as monitoring and enforcements. Higher-income households possess better bargaining power and have better access to transportation and information, as well as being members of farmer organizations. Hence, enhancing high-value crops production and marketing and in turn improving the livelihood of smallholders highly depend on minimizing market imperfections. This may require policy makers to focus on establishing appropriate institutions, improving market information systems, developing rural infrastructure, strengthening farmer organizations, resolving financial constraints through credit, enhancing value-added capacities, encouraging competition and encouraging investment that accelerates future vertical and horizontal integration.

Banana Value Chains in Central America – Options for Smallholders in Domestic and Regional Markets

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Keywords: Value chain analysis, smallholder banana agroforestry systems, upgrading value chains

The dessert banana sector in Central America is divided into two main production and marketing systems, with large-scale producers of Cavendish banana supplying export markets, and smallholders producing mainly Gros Michel interplanted in coffee plantations for local and national markets. This study presents an overview of banana value chains for smallholders in Nicaragua and Honduras, analyzing profits for farmers and options for upgrading. The Gros Michel value chains in Nicaragua and Honduras differ primarily in that in Nicaragua, value chains concentrate on national markets, while in Honduras, domestic prices are lower than in neighbouring countries, motivating trade in regional value chains to Guatemala and El Salvador. Two
main types of national value chains were identified in Nicaragua: (i) a local chain, where farmers transport small amounts of bananas and sell them directly to wholesalers in the district capital where they are sold locally, and (ii) a longer chain with intermediaries buying at farm gate consisting of bulking, transport, ripening businesses, wholesalers, and retailers directed to consumers in the country’s capital. Although, in the longer chain, the share of the final price received by the farmers is lower, farmer profits are slightly higher due to a higher consumer price and lower farmer investments in transport. In Honduras, farmers usually sell at farm gate. Depending on farm accessibility, bananas are sold to intermediaries or directly to traders who export them to Guatemala or El Salvador with only 25% of the production sold on national markets. Several options for upgrading were identified in both countries: contracts with supermarkets, possibly combined with branding of the bananas based on consumer preferences for traditionally produced Gros Michel, and improved coordination with traditional buyers and intermediaries who expressed their willingness to deal directly with farmers and pay higher prices for higher quality fruits. Processing in micro-businesses was also reviewed, but represents an option for few farmers only, with limited production volumes and a requirement for other cultivars. In general, transport is a major limitation for receiving higher prices due to remoteness of the farms in coffee-growing highland areas. For the more formal contract-based market chains, requirements of minimum quantities and timing of supply imply that substantial investments in farmer organization will be necessary. Upgrading through coordination with traditional buyers might be more feasible in the short term, but farmers need to modify agronomic practices in order to improve fruit quality.
Retention of Provitamin A Carotenoids during Post-harvest Ripening and Processing of Three Popular Musa Cultivars in South Western Uganda

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Keywords: Banana, plantain, Vitamin A deficiency, β-carotene, α-carotene

Banana and plantain (Musa spp.) form an important part of the diets of communities in Uganda. Despite preliminary indications that some cultivars could be good sources of provitamin A carotenoids (pVACs), vitamin A deficiency remains a public health problem in banana-dependent regions of Uganda. The most popular Musa cultivars in south-western Uganda include two East African highland bananas (EAHB, AAA) ‘Entaraga’ and ‘Mbwazirume’ and one plantain (AAB) ‘Manjaya-Gonja’. The most common ways of preparing these cultivars are steaming (EAHB) and roasting (plantain). Retention levels of total and individual pVACs during ripening and processing of these popular cultivars were determined by HPLC. Predominant pVACs were all-trans β- and all-trans α-carotene, together constituting more than 87% of the total pVACs. ‘Manjaya-Gonja’ had a significantly higher proportion of β-carotene, while the two EAHBs had significantly higher proportions of α-carotene during ripening and processing. Although no cis α-carotenes and very negligible levels of cis β-carotene were observed during ripening, the level of cis-carotenoids increased after processing to about 10% of the total pVACs. During ripening, an increase in total pVACs was recorded with highest levels of 7319.39µg/100gdw, 6493.04µg/100gdw and 13376.89µg/100gdw for ‘Entaragaza’ (stage 5), ‘Mbwazirume’ (stage 7) and ‘Manjaya-Gonja’ (stage 7), respectively. Steaming of ‘Entaragaza’ and ‘Mbwazirume’ led to retention and an increase of between 5-10% and 46-54%, respectively in total pVACs.
Roasting, deep frying and steaming of the plantain ‘Manjaya-Gonja’ resulted in loss of carotenoids with the highest loss (58.5%) observed after deep frying in fully refined palm oil ‘Golden fry’. The Retinol Activity Equivalents (RAE) in the processed *Musa* products ranged from 315 to 445 RAE µg/100g dw. These findings indicate that with appropriate post-harvest handling and processing, these *Musa* cultivars can contribute substantially to vitamin A requirements of vulnerable groups.

**Mycosphaerella Leaf Spot Diseases and Their Effects on Banana Post-Harvest Quality**

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**Keywords:** Sigatoka diseases, greenlife, fruit quality

Banana fruits are harvested at a preclimacteric stage in order to allow sufficient time for transport and commercialization. The time between harvest and the initiation of the natural ripening process is called “green life” (GL). Many factors are closely correlated to GL, such as temperature and crop conditions. Mycosphaerella leaf spot diseases have already been shown to influence the physiological behavior of banana fruit in tropical conditions. The aim of this work was to evaluate the influence of black leaf streak disease (BLSD) and Sigatoka leaf spot (SLS) on the GL and post-harvest quality of bananas produced in subtropical conditions at Vale do Ribeira, São Paulo state. Three different treatments were carried out, with high SLS infestation, high BLSD infestation and a control plot (very low disease level). Physiological age was calculated by mean temperature sum and harvested at 700 degree days. GL was measured at a storage temperature of 20°C. Both diseases caused reduction in fruit GL up to 50% compared with GL of fruits from healthy plants, harvested at the same physiological age. Only BLSD caused a reduction in fruit weight (40%), which is possibly explained by the greater virulence of this pathogen. Moreover, the respiration (CO₂) and ethylene (C₂H₄) profiles were different between treatments: fruits from infected plots showed an atypical climacteric phase, with intense respiratory activity after the climacteric peak.
Acceptance of Banana Cultivars Resistant to Black Leaf Streak by Consumers of the Brazilian Northeast Region

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Keywords: Musa spp., sensory analysis, preference mapping

Black leaf streak is devastating to traditional banana cultivars. In Brazil, resistant cultivars are being developed but if the consumer’s preference is not taken into account, the breeding program may not succeed. In this work, the acceptability of four resistant cultivars (‘Preciosa’, ‘Pacovan Ken’, ‘Thap Maeo’, ‘Caipira’) was assessed in the Brazilian Northeast region and compared to four susceptible commercial cultivars (‘Prata’, ‘Prata Anã’, ‘Pacovan’, ‘Grande Naine’). Two groups of consumers participated: young adults and housewives. The hedonic scale was applied to external appearance of bunches (global appearance, size, colour), acceptance of fruit attributes (appearance without peel, aroma, flavour and texture) and overall acceptance. Preference and purchase intent were also evaluated. Data were submitted to Anova and Preference Mapping. Results revealed that women and young adults showed similar opinions. They preferred ‘Pacovan’, which differed from resistant cultivars more in relation to the appearance of the bunch than the attributes associated with the palatability of fruits. Among the resistant cultivars, ‘Preciosa’ and ‘Caipira’ reached the highest levels of acceptance with respect to global appearance of the bunch, but ‘Thap Maeo’ was not accepted due to its small fruit size. ‘Pacovan Ken’ was one of the less preferred cultivars in the Ranking Preference test for bunch’s appearance, but considering only the sensory attributes of the fruit, this cultivar showed similar acceptability as the susceptible ‘Pacovan’. ‘Caipira’ showed high rejection in the purchase-intent test. Results indicate that ‘Preciosa’ could substitute the commercial ‘Prata’ and ‘Pacovan’ cultivars without impairing global acceptability, but ‘Pacovan Ken’ still needs to be improved regarding its appearance in order to replace ‘Pacovan’ for consumption.
Preliminary Study on the Potential of Banana Sap as a Dyeing Agent for the Adinkra Industry in Ghana

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Keywords: Bridelia micrantha sap, plant dye, kente industry

A study was carried out to explore the potential of banana sap as a dye for the Kente weaving industry in Ghana. Freshly harvested pseudostem was weighed and chopped into smaller bits. The chopped pseudostem was pounded in a mortar with a pestle and the sap strained. The extract was stored in a stainless bowl at room temperature. The Bridelia dye was made by boiling the bark of Bridelia micrantha and straining the sap. Plain white cotton cloth of a yard was cut into equal sizes for dyeing. The treatments were: sole banana sap; sole Bridelia dye; 50% Bridelia dye and 50% banana sap; 20% Bridelia dye and 80% banana sap; 80% Bridelia dye and 20% banana sap; and a control, with four replications. A consumer preference study was also conducted to assess the acceptability of the products developed. The results revealed that adding banana sap to Bridelia dye ensured a more consistent and intense coloration of fabrics. It also showed that banana sap could serve as a good mordant. The results from consumer acceptability tests showed that the product from 50% banana sap and 50% Bridelia dye had a good acceptance by consumers. The deep brown colour of the cloth was also preferred by many people as a peculiar product used by royals. The results showed that dyes with no or little Bridelia dye inclusion showed no sign of solidification. It could be concluded that equal volumes of banana sap and Bridelia dye could be used for the Kente industry as an alternative for the sole Bridelia dye that requires a mordant. This would reduce the cost of buying and using synthetic dyes. Further study should be conducted to explore the potential of other banana and plantain saps as a dyeing agent for the Kente industry in Ghana.
Selection of Banana Hybrids for Ornamental Purposes

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**Key words:** Cut flowers, mini-fruit, landscaping

The banana germplasm collection maintained at Embrapa Cassava and Fruits has several accessions with high potential for ornamental uses, such as potted plants, cut-flowers and mini-fruit production. We have generated 449 hybrids by crossing 16 accessions, which were evaluated for plant height, leaf colour, size and number of fruits, colour and shape of the male bud and resistance to Sigatoka leaf spot and Fusarium wilt. Plant height ranged from 63 to 168 cm, being possible to select genotypes with short stature for use as potted plants and landscaping. A wide variation in the colour of the male bud was observed, such as light pink, dark pink, red, lilac and purple. Genotypes with erect bunches, small fruits and male buds with different colours were selected for cut-flowers. As the use of banana mini-fruits in floral arrangements is a novelty in the market, hybrids with small fruit (5-8 cm) with different colours (green, pink or purple) and more than eight hands per bunch were also selected. All the selected hybrids are resistant to Sigatoka leaf spot and constitute excellent candidates for cultivar development in the near future.

Towards a More Sustainable Banana – Limitations and Strengths of a Territorial Approach

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**Keywords:** Environment, marketing

In addition to Global GAP certification, increasing volumes of tropical fruit are exported with organic, fairtrade or Rainforest Alliance certifications. In the debate on sustainable supply chains of tropical agricultural products, important issues emerge, such as sustainable land and water use, biodiversity, climate change, waste disposal, integrated pest management, nutrient cycles and soil conservation. Recognition of the importance of these items implies
challenges beyond existing certifications: (1) Existing certifications only partially acknowledge these emerging issues; (2) The existing standards are uniform, not accounting for contextual heterogeneity or opportunities to develop more sustainable supply chains; (3) Existing certifications are focused on the farm, the product or the organization, but not on the territory, the watershed, the agro-ecosystem and the wider context of local and regional institutional settings. With these challenges in mind, in 2011, Agrofair and the TASTE foundation contracted local environmental NGOs to carry out territorial studies in South Ecuador and North Peru, two important organic banana-producing regions. The agro-ecological settings and the production systems in these two regions are quite different. In North Peru, an arid zone depends on irrigation, with smallholders who cultivate banana plots of 1 hectare or less, in monoculture systems. In South Ecuador, production is in a semi-humid zone, with medium-sized producers and agroforestry systems (cocoa – forest – banana) in the hillsides. A second dimension of the study project assessed the feasibility to introduce a banana with a “denomination of origin”: “mountain-grown banana” (Ecuador) or “savannah-grown banana” (Peru). Could such denominations of origin convey specific sustainability messages, along with organic and fairtrade certifications? A rapid survey among five supermarkets in the Netherlands and Belgium learned that the retail sector is not waiting for complex messages as distinctive feature of bananas that may have their origin in very different regions, but which are physically the same: Cavendish bananas. Both studies contributed to a deeper understanding of sustainability issues for banana production in different contexts: the desert and the mountains. In Peru: the importance of guaranteeing access to water for irrigation, the risks related to climate change and the role of the banana plantations as shelter for wildlife, where the dry tropical forest habitat is under pressure. In Ecuador: the importance of the agroforestry systems for biodiversity conservation and watershed management, and, in order to remain viable, the urgent need for raising productivity. Opportunities to establish alliances of a new kind to enhance systemic sustainability also became visible. Promotion of savannah and mountain bananas via a kind of “branding” seems complicated. However, there are signs that supermarkets are receptive for a more comprehensive approach of a more sustainable banana, within the framework of corporate responsibility schemes. This would open new handling perspectives for the promotion of a banana with added environmental value.
Physical Fruit Characterization of Banana Cultivars in the Brazilian Coastal Tablelands: The First Cycle

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Keywords: Orchard, Musa spp., genotype, postharvest

Banana is one of the most consumed tropical fruits in the world. In Brazil, banana is grown in almost all regions due its huge diversity of varieties which favour adaptation to different edaphoclimatic conditions. Physical characteristics of banana fruits are important factors in the selection of cultivars in order to meet quality and market standards. We aimed to evaluate physical fruit characteristics of different banana cultivars grown under the edaphoclimatic conditions of the Coastal Tablelands of Sergipe State in the first production cycle. Evaluations were conducted at Dores Experimental station, Sergipe State, Brazil, in a randomized block design with 22 cultivars and three replicates. Each plot had six clumps and the experimental unit consisted of a fruit taken from the middle of the second hand of the cluster. The following fruit parameters were evaluated: fresh mass with and without peel (g), diameter with and without peel (cm) and, straight and curved length (cm). The cultivar ‘Maravilha’ had the highest fresh mass with peel (202.25 g) while the cultivar ‘Prata Anã’ showed the lowest values for this parameter (101.1g). Fruit fresh mass without peel followed the same pattern of those with peel. Fruits of the cultivars ‘Caipira’, ‘Prata Anã’, ‘Grande Naine’ and ‘PA42-44’ were characterized by smaller diameters with and without peel. Overall, fruits of the cultivars ‘Bucaneiro’, ‘Prata Anã’, ‘Grande Naine’, ‘FHIA-23’, ‘PV79-34’, ‘Maravilha’, ‘Japira’, ‘PA94-01’, ‘FHIA-02’ and ‘Garantida’ had longer straight and curved lengths. Banana cultivars varied widely in fruit weight, diameter and length, highlighting the potential for selecting cultivars with different commercial characteristics to distinct market sectors.

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Physical and Chemical Characterization of Banana Genotypes in Organic Systems

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Key words: Performance, varieties, parameters

The banana crop (Musa spp.) provides income, employment and nutritional value as food for producers in the Northeast of Brazil. Based on this, an observation unit was installed to evaluate the agronomic performance of five genotypes: ‘PA 4244’ (AAAB), ‘PA 9401’ (AAAB), ‘Mãe Tropical’ (AAAB), ‘Nanicão’ (AAA) and ‘Maravilha’ (AAAB). Different from the conventional system that utilizes intensive mechanization and chemical fertilizers, this experiment was conducted with a micro-sprinkler irrigation system, organic fertilizers and without soil mobilization. The objective was to evaluate the physical and chemical characterization of the five varieties under an organic production system. The post-harvest experiment was conducted at the IF - Sertão Pernambucano, Campus Petrolina, in the Chemistry Laboratory, with harvested fruits at physiological maturity and maintained under environmental temperature until their complete horticultural maturity, when they could be consumed. The analyses of physical and chemical parameters were: pH, soluble solids (°Brix), titratable acidity (% malic acid), relationship SS/TA, humidity and dry matter. The studies were performed utilizing four fruits per genotype in a completely randomized design with three replicates. It was found that all varieties reached the standard for use “in nature”. ‘Mãe Tropical’ and ‘Nanicão’ presented the highest values of soluble solids (22.4 and 21°Brix, respectively) and the lowest acidity (0.093 and 0.052%, respectively). The pH was between 4.3 to 4.9, and the variety ‘Nanicão’ got the highest value. The varieties with highest SS/TA were ‘Nanicão’ (392), ‘Mãe Tropical’ (240.5) and ‘PA 4244’ (233.5). All the varieties also presented possibilities for industrial use, with humidity percentages varying between 72.1 and 76.14% and dry matter between 24 and 27.9%. ‘Mãe Tropical’ was the most promising variety. The adoption of a banana organic system produced fruits with good organoleptic qualities similar to conventional production systems.
Volatile Profile: A Comparison between ‘Nanicão’ and ‘Prata’ Banana Cultivars at Low Temperatures

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Keywords: Musa acuminata, cold storage, tolerance, gas chromatography, mass spectrometry

Banana flavour is a widely appreciated attribute. The aroma, responsible for fruit flavour, is highly susceptible to low storage temperatures. Refrigeration is extensively used to increase fruit shelf-life, but it seems to act negatively on several physiological and biochemical processes of the fruit which are possibly involved in the cold tolerance of the cultivar. The present work investigated the volatile composition of banana fruit of cultivars ‘Nanicão’ (AAA) and ‘Prata’ (AAB) under cold storage, at 13°C for ‘Nanicão’ and 10°C for ‘Prata’ during 15 days. Thereafter, the temperature was changed to 19°C until senescence. The control group was maintained at 19°C. Volatile compounds from the headspace were isolated by a solid-phase, micro-extraction method with DVB/CAR/PDMS fibre and identified by gas chromatography – mass spectrometry. During ripening, 46 and 56 compounds were identified for ‘Prata’ and ‘Nanicão’, respectively. Before the ethylene peak, aldehydes and alcohols were the only functional groups detected. After the ethylene peak, esters were the main compounds in both cultivars (57.6% for ‘Prata’ and 61% for ‘Nanicão’), followed by alcohols, ketones and aldehydes. Cold storage induced changes in the volatile profile in comparison to the control group. The result of the Principal Component Analysis revealed a higher influence of cold storage in ‘Nanicão’ than in ‘Prata’. Esters such as 2-pentanol acetate, 3-methyl-1-butanol acetate, 2-methylpropyl butanoate, 3-methylbutyl butanoate, 2-methylpropyl 3-methylbutanoate, butyl butanoate, and pentyl butanoate, reduced drastically in the cold group in ‘Nanicão’. Our results suggest that the metabolism responsible for the production of volatile compounds correlates with cold tolerance.
Characterization and Use of Resistant Starches of the Plantain ‘CENSA ¾’ (AAB)

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Plantains are high-energy food, either as fresh fruit, homemade preparations or industrial products. A renewed interest in plantains has emerged due to some of its functional properties as resistant starches (RS) and usability for food formulations. Clinical studies show that the physiological properties of RS are beneficial for humans in helping to prevent diseases. Little is known, however, about process occurring in the starch structures in different physiological stages of the bunch development and during the preparation of plantain products. In this work, we studied the effect of the physiological stages of bunches (9 and 11 weeks) of the plantain cultivar ‘Censa ¾’ (AAB) on the content of RS for flour production. No differences were found regarding physiological stage of the bunch and RS content. Subsequently, we developed fettuccini pasta based on plantain and wheat flours (40% / 60%), which was evaluated in term of preference and acceptance compared to similar products in the market. Lowest values of preference were obtained in the plantain-based fettuccini due mainly to its raw appearance. Further efforts and strategies to improve the consumer acceptance of pre-processed plantains products, highlighting nutritional benefits, functional properties and attractive appearance are presented.

Eating Quality Preference of Alternative Dessert Banana Cultivars

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Keywords: Taste

Commercial and domestic banana production in Hawaii is threatened mainly by the presence of Banana bunchy top virus (BBTV). Traditionally, imported and locally grown Cavendish (‘Grand Nain’ and ‘Williams’) bananas along with locally grown ‘Santa Catarina’ (Apple) bananas comprise nearly the entire market of dessert bananas. Any other cultivars sold would be considered
alternative cultivars. Some alternative cultivars may be potentially BBTV resistant or tolerant, but they would likely have different tastes and textures as compared to Cavendish and ‘Santa Catarina’ bananas. The aim of this study was to rate consumer fresh eating preference between six different dessert banana cultivars - the traditional ‘Grand Nain’ and ‘Santa Catarina’, as well as the alternative ‘Niyarma Yik’, ‘Inyoya’, ‘Mbirabire’, and ‘Ney Poovan’ - to test the hypothesis that some alternative dessert banana cultivars would be rated equally or higher than imported ‘Grand Nain’ and locally grown ‘Santa Catarina’. Small portions of each banana cultivar fruit were consumed by 66 volunteers on the University of Hawaii at Manoa campus. The participants were asked to rate them in terms of overall preference on a Likert scale from extremely dislike to extremely like. ‘Niyarma Yik’ had the highest average score and was the only cultivar with a significantly different higher score from any other. All other cultivars were rated as statistically equal with each other and were overall liked. In conclusion, farmers in Hawaii could feasibly plant alternative cultivars and consumers would likely purchase them based on eating quality as compared to ‘Grand Nain’ and ‘Santa Catarina’.

Quality of ‘Prata Anã’ Banana Fruits Fertilized with Organic Compost

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This work aimed to evaluate the effect of organic fertilizer rates on fruit quality of ‘Prata Anã’ in two productions cycles. The present study was carried out in the FCA/UNESP, Botucatu-SP. The source of organic fertilizer was produced using wood residue and bovine manure, that constituted the treatments (organic compost rates): 0, 43, 86, 129 and 172 kg of compost/plant, corresponding to 0, 98.5, 197.0, 290.5 and 394.0 g of K₂O/plant, and the compost rates were calculated based on the quantity of potassium contained in the compost. The quality of fruits produced in 4th and 5th cycles was evaluated by parameters of firmness, pH, titratable acidity, soluble solids, starch and potassium tenors in the pulp. These analyses were accomplished only at harvest, since only at the point of harvest the fruits set on the same maturity conditions. The experiment was arranged in randomized block design, with five treatments, five replicates and three fruits per plot. The obtained data were submitted to variance and regression analyses. Fruits presented medium firmness of 831 and 946 gf for 4th and 5th cycles, respectively, average content of soluble solids of 3.82ºBrix (4th cycle) and 3.80ºBrix (5th cycle), average pH values of 5.60 (4th cycle) and 5.70 (5th cycle), mean acidity level of 0.16 g/100g
(4th and 5th cycles), medium starch content of 49.8% (4th cycle) and 36.1% (5th cycle) and average potassium content of 17 g/kg (4th cycle) and 20 g/kg (5th cycle). The quality attributes of fruits showed little response to differential rates of organic fertilizer, although it was shown that 5th cycle fruits receiving no fertilization showed lower potassium tenors in the fruits than those from plants that received fertilization.

Application of Antioxidants and Calcium Chloride in the Maintenance of Firmness of Fresh-Cut ‘Prata’ Banana


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Keywords: Musa AAB, ascorbic acid, cysteine, minimal processing

The present work studies the use of antioxidants and calcium chloride (CaCl₂) on ‘Prata’ (AAB) banana, stored at 8°C and 95% relative humidity. A DIC design was used in a 5 x 8 factorial with three replicates, with treatments: control, CaCl₂ 1.5% + L-cysteine (CIS) 1.0%, CaCl₂ 1.5% + ascorbic acid (AA) 1%, CaCl₂ 1.5% + citric acid (AC) 1%, CaCl₂ 1.5%, CIS 1.0%, AA 1% and AC 1%; evaluated daily up to 4 days. Each experimental plot was composed of 150 g of sliced banana fruit wrapped in a polyethylene terephthalate. Fruits at ripening stage 6 were treated with sodium hypochlorite (500 ppm), peeled and manually sliced and immersed for 2 min. The microbiological analysis did not detect thermotolerant and total coliforms or Salmonella sp., although low levels of fungus and yeast were detected. The application of antioxidant positively influenced the appearance of fruits, mainly from the 3rd day of storage. The variable firmness, soluble solids (SS), pH, ascorbic acid and titratable acidity were influenced interactively by treatments and storage time. A linear decrease in firmness and a linear increase in SS content were observed throughout the storage. Slices treated with CaCl₂ alone and associated with antioxidants had a lower loss of firmness. Ascorbic acid levels decreased quickly in control treatment during storage, while the other treatments had less marked reductions. The mass loss was only influenced by storage period, and there were no interactions among the studied factors. A linear increase in mass loss was observed, regardless of treatment, although it did not reach 1%. The results show that CaCl₂, associated or not, was effective in maintaining firmness. The treatments CaCl₂ 1.5% + CIS 1.0% and CaCl₂ 1.5% + AA 1.0% were more
effective in maintaining good appearance of fresh-cut banana and preventing browning for up to 4 days.

**Relationship between Heat-Induced Disease Resistance and Ethylene Signalling Transduction in Harvested Bananas**

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**Keywords:** Postharvest disease, physical control, molecular biology, mechanism, defense pathway, salicylic acid, jasmonic acid

Banana (Musa spp.) is the main fruit traded worldwide and is susceptible to decay caused by pathogens during storage and shipment, which significantly affects its storage life and quality. Over the past half century, chemical fungicides have been the major weapon against post-harvest diseases. Regular use of chemicals, however, has not only caused resistance in many pathogens, but has also produced negative effects on the environment and on human health. As a potential physical alternative to preserve fresh fruits and vegetables, heat treatment has been widely studied, but the mechanism of controlling post-harvest decay was not sufficiently understood. In this study, we investigated the role of ethylene response sensor 1 (MaERS1) and ethylene response factor 1 (MaERF1) in heat-induced disease resistance in harvested banana of ‘Brazilian’ (AAA). Heat treatment decreased the disease incidence and lesion sizes. Heat also enhanced expression of phenyl-alanine ammonia lyase (MaPAL) and lipoxygenase (MaLOX). As PAL and LOX were reported to be involved in biosynthesis of salicylic acid (SA) and jasmonic acid (JA), respectively, this suggests that heat could promote SA and JA biosynthesis at the same time during the induction of disease resistance. Heat weakened the MaERS1 expression level, suggesting that heat as a physical signal could be perceived by tissues of bananas through inhibiting genes transduction of ethylene receptors. Heat increased the MaERF1 expression level, indicating involvement of MaERF1 in heat-induced disease resistance. In conclusion, the mechanism of the involvement of ethylene signal transduction in heat-induced defense against diseases is linked to heat perception by bananas through repressing ethylene receptor gene expression, such as ERS1, and through enhancing ERF expression to activate PAL and LOX gene transcription, thus increasing SA and JA biosynthesis, which finally triggered disease resistance.
Bioactivity of Plant Extracts and Essential Oils in the Control of Crown Rot of Banana

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Keywords: Antifungal activity, Fusarium moniliforme, phytopathogens

Fusarium moniliforme and Colletotrichum musae are phytopathogens responsible for banana crown rot. These fungi cause considerable damage to post-harvest fruit quality. There is a need to develop new and acceptable pre- and post-harvest disinfection methods. The use of natural products, either directly as crude preparations or as pure compounds, can be an attractive method for post-harvest disease control of banana fruits. The objective of this experiment was to determine the ability of extracts of thyme (Thymus vulgaris), tarragon (Artemisia draconculus), bergamot mint (Mentha piperita var. citrata), canelinha (Cróton zehntneri), purple basil (Ocimum basilicum) and the oils of andiroba (Carapa guianensis) and copahiba (Copaifera reticulata) on the development of Fusarium moniliforme in vitro. The first five oils were extracted by steam drags, after drying the vegetable in the greenhouse with air circulating at 45°C. The last two were used in natura. Two concentrations of oils were used: 5µl/ml and 10 µl/ml of medium. The incubation was realized at 25°C, for 7 days. The results show that all oils tested in 10-µl concentration were capable of inhibiting the growth of Fusarium moniliforme in vitro.
A Study of Technological Systems Employed in Banana Jam Agro-Industrial Units


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Key-words: Banana processing, additives, concentration, technological obstacles

Appropriate banana processing is very important for the reduction of post-harvest losses. One of the most relevant products generated by banana processing in the agro-industrial context is banana jam. This product can be processed on both small and large scale. However, among the products available in the market, considerable variation in the final quality urges the need for the use of different technologies for better quality and homogeneous results. The major goal of this work was to identify processing variables among 49 processing units in the States of Minas Gerais, Paraná, São Paulo and Santa Catarina, Brazil, that may result in poor-quality banana jam. Variables analysed were banana varieties, ripening point, technological systems, use of additives and main obstacles. The ‘Nanicao’ variety was the favourite one in more than 50% of the processing units, but during the off-season ‘Prata’ and ‘Marmelo’ were also processed. The majority of processing units do not use any controlled ripening procedure, and they use bananas that are fully matured when processed. Among the legally allowed additives, the most common were acidulants (47%). Conservants ascorbic acid, benzoic acid and its salts were used in 13% of the processing units. Thickener (pectins) was used only in 6% of the total units. Most concentrators are made of copper (45%). The average cooking time was 2 hours. Major obstacles observed were related to quality and quantity of raw material and final product concentration. The quality of banana jams can be significantly improved by the adoption of some technologies and procedures as the control of ripening and the use of thickeners to standardize concentration and decrease cooking time.
Effect of Unripe Plantain Fruit Maturity on Composite Wheat-Plantain Flour Dough and Bread Quality

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A study was conducted to determine the effect of fruit maturity (7-10 weeks after full finger development) on bread dough handling properties as well as quality of wheat-plantain composite bread. Composite flours were produced by diluting wheat flour (WF) with plantain flour (PF) between 0 and 20% (w/w). The rheological properties of the composite flour dough were determined using Brabender Farinograph and Chopin Alveograph. The physical characteristics (loaf weight, volume, specific volume, crumb softness index, crust and crumb colour) and sensory quality of the bread samples were determined on a fresh basis. The water absorption, dough development time and stability indices ranged between 58.7 and 59.2%, 1.5 to 2.5 min and 3.0 to 4.0 min, respectively. Dough tenacity and extensibility were significantly affected ($P<0.05$) by PF addition. Extensibility of the composite dough reduced with increased PF addition at the 8th and 10th week of fruit maturity. The main effects and the interaction of the independent factors studied did not affect most of the loaf’s physical properties except the weight. However, bread from PF at 10th week maturity and 20% WF substitution had a significantly firmer crumb than 100% WF. Addition of PF generally reduced the sensory acceptability of the composite bread samples. Bread samples made from 10% PF at maturity period not less than 9 weeks were scored higher in terms of sensory acceptability.

Preference Mapping of Different Ratios of Banana and Araça-Boi in Jam Production

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Keywords: Jelly, sensory evaluation, physico-chemical analysis

Banana, grown in tropical and subtropical regions, is a popular fruit worldwide. As a climacteric fruit, it is extremely perishable, causing high post-harvest losses. Jellies are the second most important product of commercial
importance for the Brazilian fruit-canning industry. Jelly is easy to be produced, adds value to the fruit, allows preservation for a prolonged period and allows the development of new flavours through fruit mixtures. The araçá-boi is native from the Amazon and has acid, juicy pulp, with a pleasant aroma. Its acidity limits its use, but if associated with low-acid fruits such as banana, makes it an interesting alternative for the development of processed products, like jellies. In this context, the objective of this study was to develop and sensorially evaluate mixed fruit jellies, produced with banana (B) and araçá-boi (AB) with the following formulations: F1 (70% B: 30% AB), F2 (60% B: AB 40%), F3 (40% B: 60% AB) and F4 (30% B: 70% AB). The acceptance test was conducted using a hedonic scale of seven points, for the attributes colour, aroma, texture and flavour. The data were subjected to Principal Component Analysis to obtain the internal preference mapping. The four formulations showed good acceptance regarding colour. For the texture attribute, F1 and F2 were considered equal by consumers, with the formation of three distinct groups (F1 + F2, F3 and F4). The aroma and flavour were responsible for greater discrimination between jellies by consumers, with greater preference for F1 and F2, and lowest for F4. The mixed fruit jellies, F1 and F2, containing 70% and 60% of banana, respectively, were accepted for all attributes and were preferred for flavour and aroma, therefore proving suitable for industrial processing.

Development of Whole-Apple Fuji Cake Enriched with Apple Banana Peel

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Keywords: Waste, use of fruit peel, dietary fiber

Brazil experiences waste of food products throughout the food production chain. The development of new products from the complete use of the food product can help minimize this problem. Fruit peel contains important constituents that are sources of dietary fibre, minerals and vitamins. Offering products that possess higher nutritional value and are affordable by lower class provides an alternative means to increase nutrient intake. Thus, the objective of this work was to develop a whole-apple cake, enriched with banana peel, and to
determine its chemical composition, as well as to evaluate the percentage of dietary fibre of the product. Fuji apples (7.21%) and apple banana peel (13.11%) were chopped and boiled in water and sugar for 9 min. The other ingredients [milk (23.62%), wheat flour (19.68%), sugar (18.36%), eggs (5.90%), margarine (3.93%), baking powder (3.28%), salt (0.65%) and cinnamon (0.33%)], were mixed and the homogeneous mixture was baked at 180°C. After processing, portions of 25 g were packed and kept frozen (-18°C) for chemical analyses, according to official methodology. The results were similar to the results described in literature and showed that 110 g of cake contains 40.98 g of moisture, 2.78 g of ash, 9.13 g of lipids and 41.55 g of carbohydrates; the caloric content was 263.17 kcal. However, the new product showed significant total fibre content of 4.93 g, being 3.17 g of insoluble fibre and 1.77 g of soluble fibre. Therefore, the development of this cake is a viable option for the use of banana peel, since it not only reduces organic waste and promotes food safety through conscious consumption awareness, but also adds nutritional value to the product.

Cake Made with Apple Banana Peel and Apples Fuji: Sensory and Microbiological Evaluation

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Keywords: Use of fruit peel, microbiological evaluation, sensory evaluation

Fruit waste occurs in both the production chain and the domestic environment. Although fruit peel contains considerable amount of nutrients, it is usually discarded. However, the development of products with this by-product adds nutritional value and prevents waste. Banana peel contains more fibre than the pulp and can be used to enrich or substitute ingredients in formulations, besides providing flavour and aroma differentiation. The objective of this work was to evaluate the microbiological quality (coliforms at 35 and 45°C, Salmonella sp., moulds and yeast) and the sensory characteristics of apple cake enriched with apple-banana peel. After being sanitized, the apples (7.21%) and the banana peel (13.11%) were chopped and boiled in water with sugar for 9 min until a syrup was obtained. The rest of the ingredients (eggs, sugar, wheat flour, milk, baking powder, salt, cinnamon) was added and the batter was baked at 180°C. An affective acceptance test, based on a 9-point
hedonic rating scale, was carried out with 121 untrained panellists to evaluate sensory attributes as well as purchase intention. A mean test was conducted with the obtained grades. All sensory attributes showed good acceptance, with average grades over 8 (really liked), being 8.69 for appearance, 8.67 for colour, 8.79 for aroma and 8.72 for flavour, and 86% of the panellists stated they would purchase the cake. The cake presented an acceptable microbiological profile, within the standards of the Brazilian Legislation, so the alternative to use banana peel to enrich the formulation can be considered viable for healthy and sustainable eating, besides having been approved by potential consumers.

**No Waste in Musa Species: The use of Banana and Plantain Leaves in the Production of Edible Mushrooms**

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**Keywords:** *Pleurotus pulnonarius, Pleurotus ostreatus,* value addition, technology adoption

In most parts of the world, production of banana and plantain gives rise to large quantities of leaves and pseudostems which can constitute a major waste-disposal challenge, especially after bunch harvest. These agricultural wastes are usually left in situ to decay. In an attempt to reduce this waste, an investigation was carried out using dry leaves of some banana cultivars (plantain ‘Agbagba’, banana ‘Fugamor’ and cooking banana) as a growth medium in the cultivation of two edible mushrooms (*Pleurotus pulnonarius* and *Pleurotus ostreatus*). The result revealed that all the cultivars supported the growth of the mushrooms, with *P. pulnonarius* giving a higher yield than *P. ostreatus*. However, when considering some growth parameters of the mushrooms (mycelia extension, production efficiency, biological efficiency), it was observed that cooking banana gave better results than plantain. This paper further discusses the income that may be accrued to farmers that may wish to engage in this venture.
Contribution of Banana to the Food Security and Nutrient Intake of People Living with HIV and AIDS (PLWHA) in the Lake Victoria Basin

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**Keywords:** Dietary diversity score, nutrient enhancement, recommended daily allowances

A survey was undertaken in Rachuonyo (Kenya), Bukoba (Tanzania) and Rakai (Uganda) districts to assess the contribution of banana to household food security and nutrition of PLWHA. Data were collected through interviews with 373 PLWHA, key informants and focused group discussions. The majority (71.5\%) of the respondents were females aged 20-50 years; most had no higher than primary-level education and the majority were small-scale farmers. The respondents produced, consumed and sold different types of bananas. The most popular banana types were identified to be ‘Kibuzi’ in Rakai district; FHIA varieties and ‘Yangambi Km 5’ in Bukoba, and Bluggoe and Apple banana in Rachuonyo. The main attributes desired in bananas by PLWHA were taste, market value and yield. Others included drought tolerance, availability of planting materials and shelf-life. The study population was generally food insecure. Over half of the respondents indicated that their food harvests were not adequate to cater for their food needs. The dietary diversity score and energy intake were also lower than desired. Banana contributed substantially to household food intake for PLWHA in the three districts. A banana-based, nutrient-enhanced food supplement made by blending banana flour (61\%) with soybean flour (39\%) and multi-nutrient fortificant pre-mix (0.2\% of mixture) was distributed to 15 respondents and their nutrient intake estimated. The product, which contained 459.7 kcal, 15\% protein and substantial levels of vital vitamins and minerals, was well accepted and increased energy and nutrient intake by the recipients. At the recorded intake level (average of 66 g per person per day), intake of energy and a few nutrients was still below recommended daily allowances (RDA) and about 204 g of the nutrient-enhanced banana flour was required to achieve RDA.
Evaluation of Banana Fruit Marketing in the Akluj Area of Maharashtra State, India

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Banana is a popular and important commercial fruit crop grown in India. Jalgaon, Pune, Solapur, Usmanabad and Nanded are the major banana-growing districts in Maharashtra state. Akluj area was selected for the study because of high-quality production of banana fruits and high levels of major fresh banana fruit export. The prices banana fruits command depends on their quality and quantity. From a marketing perspective, this study considers various postharvest management practices, export and domestic markets, marketing costs and price spread in preferred marketing channels. Fifteen farmers were selected for this study on the basis of actual area under banana cultivation. Farmers were selected by adopting a random sampling method. The following channels have been identified in marketing of banana fruits: Channel I: Producer – local trader – commission agent – wholesaler – ripening contractors – retailer – consumer; Channel II: Producer – commission agent – wholesaler – ripening contractors – retailers – consumers; Channel III: Producer – commission agent – ripening contractors – retailers – consumers; Channel IV: Producer – retailer – consumer. When bananas pass through many intermediaries after leaving the farm gate and before reaching the consumer, these intermediaries provide services to earn profit. Producers’ share in consumers’ rupee was more in channel IV because there were no intermediaries. The highest banana fruit volumes were sold through Channel III (42.06 %), followed by Channel II (32.34 %) and Channel I (24.88 %). The per-quintal cost of marketing of ripened fruits was the highest in Channel I (Rs. 409) as compared to Channel II (Rs. 397), Channel III (Rs. 379) and Channel IV (Rs. 325). Producers’ share in consumers’ rupee was 52.31% in Channel I, 53.86% in Channel II, 55.43% in Channel III, 58.07% in Channel IV, and 53.89% overall. The share of wholesaler (5.39%) and retailer (5.39%) were substantially large.
Closing Keynote: Bananas and Plantains in Latin America and the Caribbean: Current State, Challenges and Perspectives

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Keywords: Musa, pests, diseases, production systems, quarantine

Latin America and the Caribbean (LAC), although not the center of origin of banana and plantain, grow 28% of the global production. Approximately 20 million tons (64% of production) are locally consumed and seven countries of the region are in the top ten banana exporting nations. In addition, 99% of exported plantains are produced in LAC. In spite of considerable technical change in recent decades in LAC, banana and plantain continue to face important challenges to the sector in general. Of overarching priority for the sector is strengthening quarantine procedures against Tropical Race 4 of Fusarium oxysporum f. sp. cubense, Banana bunchy top virus, bacterial wilts and other pests and diseases not yet present in LAC. Climate change and rising costs for fertilizers, fossil fuels and pesticides are also relevant challenges. Opportunities for increased grower income and a greater contribution from banana and plantain to national economies are also constrained by an underinvested research and development system. Other threats and opportunities are specific to each of the five production systems commonly occurring: (1) tropical export Cavendish production - black leaf streak (BLS) and increasing strict environmental and worker safety regulations, (2) subtropical Cavendish production - abiotic stresses, (3) monoculture plantain - BLS and water deficit, (4) banana and plantain associated in coffee and cocoa fields - Fusarium wilt (FW) and deficient marketing; and (5) mixed and monocrop banana and plantains produced at small scale for home consumption or local markets - BLS and bacterial wilt. Some countries have specific cultivar preferences and challenges, such as Brazil (‘Prata’ – AAB) and Peru (Isla and Palillo – Pacific Islands AAB) where FW is a constraint. Collaborative regional knowledge platforms may offer increasing benefits, especially with more sophisticated electronic tools for knowledge sharing, identification of homologue and analogue zones, crop, climate and pest
modeling, tools for the study of soil and root health and genomics. A greater focus of markets and value chains is also emerging to link changes in production technology with improved marketing.
Workshops

Workshop 1: Musapedia: Towards Developing a Trustworthy Source of Knowledge on Bananas

Conveners: Anne Vézina¹, Raffaella Roviglioni² and Inge Van den Bergh¹

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Keywords: Knowledge management

Every year, hundreds of articles on bananas are published in scientific journals, not to mention the bulging ‘grey literature’. Whereas the main challenge for scientists in rich countries is finding the time to extract the relevant information from the expanding knowledge base on bananas, accessing it is more often than not the main problem of researchers in poorer countries. As a network that puts a premium on facilitating the exchange of information, knowledge and know-how on banana, ProMusa set up a knowledge resource centre on its website to address these issues of access and information overload. It initiated the process by adopting a user-centred approach to identify in more detail the goals, needs and attitudes of the target user-groups. ProMusa members from different regions and representing different user-groups and levels of engagement within the community were interviewed. Their goals (what they want from the website) were then integrated with the management constraints of developing the resource centre. An online collaborative tool for compiling knowledge that would be reviewed by experts for its accuracy emerged as the top priority. We present the process that led to the conception of Musapedia and the challenges of developing an up-to-date and trustworthy source of knowledge about bananas.
Workshop 2: Future Directions in *Musa* Genomics and Applications in Genetic Improvement

**Conveners:** Nicolas Roux\(^1\) and Robert Miller\(^2\)

\(^1\)Bioversity International, Parc Scientifique Agropolis 2, 34397 Montpellier Cedex 5, France; \(^2\)Universidade de Brasília, Campus Universitário Darcy Ribeiro, Instituto de Ciências Biológicas, Departamento de Biologia Celular, Asa Norte, CEP 70.910-900, Brasília, DF, Brazil

The workshop on future directions in *Musa* genomics and applications in genetic improvement proposes to expand awareness of today’s developed genomic resources and available technologies, and identify mechanisms to promote their long-term application in *Musa* genetic improvement. The meeting is an ideal forum for such an initiative, with the presentation of the first whole-genome sequence for *Musa acuminata*, accession DH Pahang, which was completed in the framework of Global *Musa* Genomics Consortium.

The following outputs will be developed by the workshop participants:

1. Raised awareness among the banana research community about the applicability of the whole-genome sequence for *M. acuminata* in genetic improvement;
2. Strategies identified for enhancing organization and access to centralized genomic resources and accelerated application in *Musa* crop improvement;
3. Priority areas of research identified in *Musa* genomics;
4. Core collections for genomics: priorities identified for conservation and characterization of germplasm;
5. Initiatives identified for boosting the global partnership for conventional breeding and intensifying the production of new *Musa* cultivars.

The workshop will begin with general overview presentations of applications in other crops of genomics in non-conventional improvement, followed by summaries of the *Musa* genetic improvement-related issues presented during the symposium and *Musa* Genomic resources available today. Working groups will then discuss priority areas of research for *Musa* genomics, identify strategies for optimizing genomic resource management and application in crop improvement, define priorities for germplasm core collections, and identify mechanisms for boosting global partnerships for conventional breeding.
Workshop 3: Pests and Diseases in Bananas – Projecting the Effects of Climate Change

Conveners: Charles Staver\textsuperscript{1}, Miguel Dita\textsuperscript{2} and Luis Pérez Vicente\textsuperscript{3}

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Over several decades, ProMusa has addressed important disease threats such as black leaf streak (black Sigatoka), Fusarium wilt, banana streak viruses and Banana bunchy top virus. The workshop on climate change during ProMusa 2011 proposes to expand the bases for more effective projection of climate-change effects of banana pests and diseases. Brazil is an excellent venue for this groundbreaking effort, since EMBRAPA has a substantial research project CLIMAPEST on this subject. The CGIAR-led initiative on climate change CCAFS (Climate Change Agriculture and Food Security - http://www.ccafs.cgiar.org/) is also developing numerous electronic tools and focused initiatives. The ProMusa and regional banana networks offer considerable advantages for banana and plantain to be highlighted as a test crop for CCAFS. The workshop participants will develop the following outputs:

1. raise awareness among the banana research community about the available tools for understanding the implications of climate change for banana production with focus on pests and diseases;
2. compile and discuss an inventory of on-going and planned research on climate change effects of banana and its pests and diseases;
3. identify preliminary parameters for modelling the effects of climate change on different banana cultivar groups and key pests and diseases;
4. identify initiatives to be undertaken by ProMusa working groups on the theme of climate change

The workshop will kick off with keynote addresses from two scientists from EMBRAPA’s CLIMAPEST initiative Dr Raquel Ghini and Dr Emilia Hamada and from Dr David Turner on banana cultivar response to climate change. Working groups by important pests and diseases and by banana cultivar groups will assemble key parameters for use in modelling the effects of climate change on the banana crop and its pests and diseases.
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