

IHC2018 Symposium 4

Growing and Marketing Banana under Subtropical Conditions

ORAL PRESENTATIONS

OPENING KEYNOTE

BROAD OVERVIEW OF THE SUBTROPICAL BANANA INDUSTRY

Víctor Galán Sáuco

Isaac Albéniz 17, 38208 La Laguna, Tenerife, Canary islands, Spain

Bananas are cultivated in different countries in the subtropics, including Turkey, Israel, Egypt, Spain (Canary Islands), Australia, Morocco, South Africa, Portugal (Madeira and Azores) and south of Brazil. Despite climatic constraints which cause undesirable physiological phenomena and long cropping cycles, yield of bananas cultivated in the subtropics is excellent. Although Grand Nain is the most popular cultivar in the subtropics, Williams and some Dwarf Cavendish clones, like Gruesa, a Canary Islands selection, are also planted. Due to the climatic constraints such as low temperature and temperature fluctuation and also water scarcity, protected cultivation have gained popularity particularly in Morocco, Canary Islands, Turkey and more recently in Israel where all new plantings are actually done under greenhouse cultivation. Management of pests and diseases is generally easier and cheaper compared with the tropics, due to the limitations of low temperatures and humidity on pest and pathogen activity. In fact, most of the subtropical belt is free of Sigatoka and *Radopholus*, although the incidence of Fusarium wilt and, particularly, the continuous spread of Tropical Race 4 is a serious concern for the future. Although proximity to the market is an advantage for those subtropical countries like Israel, Turkey or Morocco which commercialise their bananas locally, strong difficulties are present for Canary Islands or Madeira which export their fruits to the Iberian Peninsula where they face the competence of the so called dollar bananas arriving from Latin American countries. The actual importance of and future prospects for developing banana in the subtropics are analysed in this paper.

Keywords: Climatic constraints, cultivars, markets, pests and diseases, protected cultivation

SESSION I: Abiotic stress management and protected cultivation

KEYNOTE

AN OVERVIEW OF BANANA PRODUCTION IN PAKISTAN: KEY CONSTRAINTS AND MANAGEMENT OPTIONS

Hadi Bux Laghari

Technical Manager Asim Agriculture Farm, District Tando Allahyar Sindh Pakistan, 092 Sindh Hyderabad, Pakistan

In 2013 - 14, 115,763 MT of Dwarf Cavendish bananas were produced on about 27,899 ha in subtropical Sindh Pakistan, with yields ranging from 15 to 30 MT/ha. The industry struggles with a number of problems, including low productivity per ha, poor bunch quality and seasonal gluts in local markets. A survey was conducted to identify key constraints and management options for local Pakistani banana production. In June 2014 five banana producers from different locations were interviewed, and their plantations surveyed. The survey identified eight major problems: i) excessive planting density (above 4,500 plants/ha); ii) single bunch cycles in which 90% bunches coincided with the peak of the extremely hot summer (June and July); iii) variations in bunch quality and quantity according to soil types; v) extremely hot summers; vi) droughts and irrigation water shortages; vii) occasional frost bite during winter, and viii) poor management. All constraints contributed to low productivity, low bunch-quality and fluctuations in year-round fruit availability in local markets. Several crop management practices were tested on one acre plantations of each banana producer that was surveyed between February 2015 and April 2017. Soil samples were taken and analyzed, population density was thinned to between 1,976 and 2,470 plants/ ha. Soils with an electrical conductivity



(EC) between 0.50 and 1.50 dS/m with a heavy clay and clay loam texture, as well as sandy/silty loams with an EC less than 0.50 dS/m were selected in irrigation water-deficit areas (independently from the soil type). A monocyclic growth cycle was used, in which bunching coincided with pleasant weather (September to November), when day-length is shortening, and daytime temperatures remain between 28 and 38 °C. There are also less winds, lengthening nights, low humidity and nighttime temperatures ranging between 16 and 24°C, all of which help reduce evapotranspiration and increase dry matter content, thus improving bunch quality. For normal soils with an EC ranging from 0.2 - 0.50 dS/m, with silty clay loam or loam textures and no irrigation water deficit, a double banana growth cycle was maintained, the first bunching from May to July, and second from September to November. November bunches may still retain good potential to survive frost bite during winter (mid-December to January). Productivity levels of 50 tons/ha for single bunch cycles and 80 tons/ha for double cycles were achieved. In addition, planting hedges of 'Grand Naine' in good production conditions with an 11 foot (3.3m) interrow distance and 3,200 plants/ha, produced of up to 150 tons/ ha. Thus the survey indicates how the identified productivity constraints can be managed to achieve higher yields.

PHENOTYPING THE BANANA BIODIVERSITY TO SELECT CLIMATE SMART CULTIVARS.

Jelle van Wesemael¹, Ewaut Kissel¹, Rony Swennen^{1,2,3}, N. Roux⁴ and **Sebastien Carpentier**^{1,2}

¹Laboratory of Tropical Crop Improvement, KU Leuven, B-3001 Leuven, Belgium.

²Bioversity International, Willem De Croylaan 42, B-3001 Leuven, Belgium.

³International Institute of Tropical Agriculture (iita.org). C/O The Nelson Mandela African Institution of Science and Technology, P.O. Box 44, Arusha, Tanzania.

⁴Bioversity International, Parc Scientifique Agropolis II, Montpellier, France

Bananas are a very important crop for the African highlands. The region faces water deficit and low growing degree days. The International Transit Center of Bioversity International holds the world's biggest collection of banana biodiversity (>1500 accessions). In the Belgian project "More fruit for food security: developing climate-smart bananas for the African Great Lakes region", we aim to evaluate the potential of our collection via phenotyping.

We have characterized the growth potential of 32 representatives of the Musa biodiversity and have ranked their growth under control and mild osmotic stress conditions. 5 representatives, representing 51 related accessions in the collection, were found to have superior growth. This growth models are being scaled up to a growtainer. Our growtainer simulates the climate of the highlands and grows 504 plants simultaneously.

To get more insight into the physiology, we monitor in a next step the individual plant transpiration of selected genotypes gravimetrically. We gained already insight in the day to day, and within day, variations of transpiration rate, of all 32 representatives under controlled conditions. We show that banana declines its transpiration rate near the end of the day, reducing transpiration water loss up to 30%. This feature is correlated to efficient water consumption and is thus a valuable, rapid screening parameter for drought tolerance. We hypothesize that this might be a feedback from photosynthesis. With sufficient root pressure and less need to fix CO₂, increase the stomatal resistance for gas exchange results in a higher water use efficiency. We have selected 25 phenotypic variables related to the transpiration pattern. Based on blind clustering within the 25 dimensional space we detect two major feedback phenotypes in the Musa biodiversity: water consuming cultivars with a late feedback, and cultivars with a balanced water usage. Breaking up, and describing the daily transpiration patterns proves useful as a cultivar selection tool, while also allowing insight in the plant physiology of transpiration.

Keywords: Agro-eco zone, crop biodiversity, high throughput phenotyping, stress tolerance

BANANA FROST PROTECTION BY THERMAL NETS IN ISRAEL

Gal Or¹, Idan Elingold², Avishi Londener², Zari Gal³, Yotam Zait⁴ and **Navot Galpaz**⁵

¹The agricultural extension service of Israel, Hamakkabim Road, Beit Dagan 50200, Israel.

²Jordan banana research station, Zemach 15132, Israel.

³Ginegar plastic products LTD, Kibbutz Ginegar 36580, Israel,



⁴The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, Faculty of Agriculture, the Hebrew University of Jerusalem, Rehovot 76100, Israel.

⁵Northern R & D, Kiryat Shmona 11016, Israel.

Banana plants are known to be extremely sensitive to frost damage. In the past four winters, the banana plantations in Israel have been exposed to a sequence of frost events. Heavy damage, including significant yield-loss and plant mortality, has been recorded.

In the past, various frost-protection strategies have been tested, including water-sprinkling, active air heating, and air turbulence, but none of them were either functional or cost effective.

The potential of using a 50% shading thermal-net, which can trap the infra-red radiation emittance that is being released by plants and the ground to the sky during radiation frost, is considered to be a new and effective tool for frost protection in bananas. To avoid shading damage, the thermal net was set as a thermal screen, only during the winter months (December 1 through March 31).

A frost event occurred in January 2016, resulted in severe visual damage to the plants grown under the control 10% shading net, whereas almost no damage was observed under the thermal net.

In the first ratoon, plants under the thermal net had grown 6% higher than the control net, and bunch weight was increased by 15% (41.5 kg and 35.3 kg, respectively).

Minimum air temperature at 2 meters under the thermal net was significantly higher than the control net (0.4 C° and -0.9 C°, respectively), and leaf temperatures were -0.3 C° and -1.8 C°, respectively. In the day after the frost event, photosynthesis under the control net was practically null, whereas photosynthesis rate under the thermal net was 25 times higher (1.75 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$).

To summarize, thermal nets have shown a great potential in frost protection of bananas. We speculate that the protection is achieved by the combination of elevation of air and plant temperature and mitigation of the radiation damage that occurs in a sunny day that follows a frosty night.

Keywords: Banana, frost protection, thermal nets

AGRONOMIC PERFORMANCES OF NEW SELECTIONS OF CAVENDISH VARIETIES (*MUSA* SPP. AAA) GROWN IN DIFFERENT PROTECTED CULTIVATION AREAS IN TURKEY

Hamide Gubbuk¹, Frederic Bakry², Dilek Guven³, Orhan Taskiran⁴ and Yvan Mathieu⁵

¹Akdeniz University, Faculty of Agriculture, Department of Horticulture, 07058 Antalya, Turkey;

²CIRAD, UMR AGAP, GABA Team, TA A-7502, Av, Montpellier, France;

³Bat305 Akdeniz Research Institute, Antalya, Turkey

⁴Food, Agriculture and Livestock Office, Anamur Mersin, Turkey

⁵VITROPIC S.A. ZAE des Avants, 34270 Saint Mathieu de Trévi, France

Protected cultivation is a beneficial cropping system to produce banana in Turkey and much more profitable than open-field conditions. Grand Nain is the most popular cultivar grown under greenhouses in Turkey. But, it is still possible to increase yields and fruit quality and subsequently grower incomes in particular by testing new varieties. The objective of this study was so to evaluate the performances of five new Cavendish varieties (CV 902, Jobo, MA13, Williams and MA 13) previously selected by VITROPIC SA in open field tropical conditions in subtropical conditions with local control (Grand Nain). All new Cavendish varieties were introduced in Turkey from VITROPIC SA Saint Mathieu de Treviers, France. All cultivars were produced by *in vitro* micropropagation of meristems, and then weaned and grown in nurseries until to reach a transplantable size (25 cm) for planting. The experimentation was carried out in three different locations (Alanya, Anamur and Bozyazi/Turkey) under greenhouses. Various parameters were recorded over two cycles including: stem circumference, stem height, total leaf number, bunch stem circumference, number of hands and finger per bunch, finger length and circumference at harvest and bunch weight. Regarding of locations, Bozyazi site showed better performances in many aspects comparison to the two other locations. Regarding of varieties, Williams cultivar had in average the highest stalk circumference and height but also the highest bunch weight (50.27 kg). The bunch weight of 'MA13' and 'CV 902' selection, were 47.65 kg and 42.66 kg, respectively whereas the control (Grand Nain) and the Jobo selection had the lowest bunch weight. Results also showed that cultivars Williams, MA 13 and CV 902 were more productive than the local control (Grand Nain) in greenhouse conditions. In addition, no somaclonal variations were observed in any of the three experimental



locations. These results suggest that the new selections might have been advantageously cropped in Turkey in protected cultivation providing higher earnings to growers in comparison to local plant material.

Keywords: Adaptation, banana, *Musa Cavendishii*, new variety, protected cultivation, quality, yield

A SIMPLE COLD TOLERANCE TEST FOR BANANA CULTIVARS

M.P Weinert¹, D.L Peasley², M.K Smith³ and A. Drenth⁴

¹NSW DPI, 1243 Bruxner Highway, Wollongbar, NSW 2480, Australia;

²Peasley Horticultural Services, PO Box 542, Peasley Horticultural Services, PO Box 542, Murwillumbah NSW 2484, Australia;

³Department of Agriculture and Fisheries, PO Box 5083, SCMC, Nambour QLD 4560, Australia

⁴Centre for Plant Science, The University of Queensland, Ecosciences Precinct GPO Box 267, Brisbane QLD 4001, Australia

Cooler growing conditions in subtropical environments adversely affect banana fruit yield and quality. Crop cycling is longer, plants and fruit can be damaged by low temperatures and bunches and fruit develop abnormally. These cooler temperatures also increase to pest and disease susceptibility in some varieties. There is also consumer purchasing resistance to the dull grey/yellow fruit exhibiting underpeel discolouration, caused by chilling. A simple, prototype, sap flow test, shows promise as a practical, objective measure of cold tolerance to support the standard evaluation measures, chlorophyll photo-oxidation, black spotting of leaves, petiole blackening and vigour ratings. The top hand from the bunch is removed from the peduncle immediately after harvest and the number of drops of sap in the first minute, from the cut surface of the hand was measured. Sap flow tests were conducted between July and November 2016 at the Duranbah variety trial site in New South Wales, Australia. None of the ten Cavendish types (AAA) tested exhibited any sap flow during winter and only two had sap flow in mid-November, well into the Australian spring. All four tetraploid varieties and two AAB cultivars and one ABB cultivar tested showed sap flow right through the winter months. Significant differences in sap flow were found between some of the cultivars. Cold tolerance is a major selection criterion for potential new varieties for the Australian subtropics and this simple sap flow test shows promise as a practical, objective measure of cold tolerance to support the standard evaluation measures.

Keywords: Chill damage, fruit quality, *Musa*, sap flow, subtropical

EVALUATION OF NETS SYSTEM ON BANANA PRODUCTION IN SUBTROPICAL CONDITIONS

Lokman Altinkaya and **Hamide Gubbuk**

Akdeniz University, Agriculture Faculty, Antalya, Turkey

Banana is one of the most important commercially grown tropical crops in Turkey. Although it has been grown in both open-field and protected cultivation, the latter one is more popular due to all year around production and higher yields and quality. In recent years, the total banana production area has increased to around 6,225 ha with production of 305,926 t of fruit. Plastic sheet is a common covering material in protected cultivation. However, the use of plastic as a covering material has a disadvantage of stopping rain-water reaching the ground. The objective of this study is to evaluate banana production in open-field and net covering system. Experiment was conducted in Gazipasa province, Antalya in years 2015 and 2016. Dwarf Cavendish cultivar was used as plant material. Galvanized iron frames and monofilament white weaving net were used for construction and covering material, respectively. During the growing period, climatic data (minimum, average and maximum temperature, relative humidity, atmospheric and soil moisture), leaf chlorophyll content, light intensity values (photometric, quantum and pyranometric), wind damage and yield were evaluated in both open-field and net covering systems. Results showed that while temperature values were higher under the net covering system, the relative humidity was lower in some months compared to open-field conditions. On the contrary, relative humidity and soil moisture records were higher in net covering systems than that recorded for in open fields. Chlorophyll content was higher in net covering systems, while means of light intensity values means were detected to be lower in net system compared to that



measured in open-field. Very little wind damage has been observed in net covering system. On the other hand, yield was found to be higher in net covering system with 44.9 t Vs 40.2 t recorded from open field.

Keywords: Chlorophyll content, net, soil moisture, temperature, wind damage, yield

EARLY COLD-INDUCED PEROXIDASES AND AQUAPORINS ARE ASSOCIATED WITH THE HIGH COLD TOLERANCE IN DAJIAO

Wei-Di He, Jie Gao, Tong-Xin Dou, Fang-Cheng Bi, Ou Sheng, Gui-Ming Deng, Chun-Yu Li, Chun-Hua Hu, Tao Dong, Rui-Bin Kuang, Hui-Jun Gao, **Qiao-Song Yang** and Gan-Jun Yi

Institute of Fruit Tree Research, Guangdong Academy of Agricultural Sciences, No.80 Dafeng 2nd Street, Wushan Road, Tianhe District, Guangzhou, China

Banana is an important tropical fruit with high economic value. One of the main species (cultivar Cavendish) is susceptible to low temperature, while another close relative specie (Dajiao), has considerably higher cold tolerance. To investigate early cold stress response of Dajiao, here we applied comparative membrane proteomics analysis for both cold-sensitive Cavendish and cold-tolerant Dajiao subjected to cold stress at 10 °C for 0, 3 and 6 h. There are 2,333 and 1,834 proteins being identified in Cavendish and Dajiao respectively. Subsequent bioinformatics analyses show that 692 Cavendish proteins and 524 Dajiao proteins are predicted to be membrane proteins, in which 82 and 137 differentially expressed membrane proteins (DEMPs) were found in Cavendish and Dajiao, respectively. Interestingly, the number of DEMPs with increased abundance at 3 h cold treatment in Dajiao (80) is seven times more than that in Cavendish (11). GO molecular function analysis of DEMPs for Cavendish and Dajiao indicates that they both belong to seven categories including hydrolase activity, binding, transporter activity, antioxidant activity, etc., but the number in Dajiao is twice that in Cavendish. Strikingly, we found two protein groups (peroxidases and aquaporins) are among the proteins, whose abundance is significantly increased at 3 h cold treatment in Dajiao. RT-PCR, multiple reaction monitoring and subcellular localization analysis, demonstrated the global membrane proteomics data are reliable. In combining with the physiologic and biochemical data, we found that membrane-bound Peroxidase 52 and P7, and aquaporins (PIP1;1, PIP2;4, PIP2;6, TIP1;3, PIP1;2), are mainly involved in decreased lipid peroxidation, and maintaining leaf cell water potential, which appear to be the key cellular adaptation contributing to the cold tolerance of Dajiao. This membrane proteomics study provides new insights into the cold stress tolerance mechanism in banana, toward potential applications for ultimate genetic improvement of cold tolerances in banana.

Keywords: Aquaporin, Cold tolerance, *Musa* spp. Cavendish, *Musa* spp. Dajiao, Peroxidase , quantitative proteomics

ANALYSIS OF THE DIFFERENT COLD TOLERANCE BETWEEN CAVENDISH BANANA AND DAJIAO BASED ON TRANSCRIPTOME AND PHOSPHOPROTEOME

Jie Gao, Wei-Di He, Ou Sheng, Gui-Ming Deng, Fang-Cheng Bi, Chun-Yu Li, Chun-Hua Hu, Tong-Xin Dou, Tao Dong, Hui-Jun Gao, Rui-Bin Kuang, **Qiao-Song Yang** and Gan-Jun Yi

Institute of Fruit Tree Research, Guangdong Academy of Agricultural Sciences, No.80 Dafeng 2nd Street, Wushan Road, Tianhe District, Guangzhou, China

Low temperature is one of the key environmental stresses which greatly affects the global banana production. To understand the molecular mechanism of the different cold tolerance between Cavendish banana and Dajiao, we used comparative transcriptomics and phosphoproteomics analyses for Cavendish banana and Dajiao subjected to cold stress. The cold-response genes at early stage are identified and grouped in both species by GO analysis. The results show that 10 and 68 differentially expressed genes (DEGs) are identified for 3 and 6 h of cold stress respectively in Dajiao, while 40 and 238 DEGs are identified respectively in banana. There are 17 DEGs found uniquely in cold-tolerance Dajiao, which were involved in signal transduction, abiotic stress, copper ion equilibrium, photosynthesis and photorespiration, sugar stimulation, protein modifications etc. We conclude that the rapid activation and selective induction of ICE1 and MYBS3 cold tolerance pathways in Dajiao, along with expression of other cold-



specific genes, may be one of the main reasons that Dajiao has higher cold resistance than banana. A significant phenotypic difference between MpMAPK3 RNAi and control plants is the transgenic plants leaves displayed severe necrosis and wilting symptoms, while WT leaves remains normal. By comparing the phosphoproteome between transgenic and wild type plants under cold stress, the result showed that there were 34 phosphoproteins which associated with oxidoreductase activity showed significant changed in WT, while no changed in transgenic plants. The results indicated that the suppression expression of MAPK3 may led to the ROS disorders in transgenic plants. MDA content in transgenic plants was significant higher than WT, and the magnification of POD activity of transgenic plants under cold tolerance was lower than WT. These research results show that the MpMAPK3 as positive regulator of cold signaling confers the cold tolerance of Dajiao by effecting ROS pathway.

Keywords: Cold tolerance, Comparative phosphoproteomics, Comparative transcriptomics, MpMAPK3, *Musa* spp. Cavendish, *Musa* spp. Dajiao

SESSION II: Fusarium wilt

KEYNOTE

CURRENT STATE OF FUSARIUM WILT OF BANANA IN THE SUBTROPICS

Miguel Dita¹, Luiz Teixeira², Wayne O'Neill³, Anthony Pattison⁴, Chunyu Li⁵, Sijun. Zheng⁶, Charles Staver⁷ and Altus Viljoen⁸

Empresa Brasileira de Pesquisa, Agropecuária (EMBRAPA), Rodovia SP 340 - Km 127,5 Caixa Postal 69, 13820-000 Jaguariúna-São Paulo, Brazil

²Instituto Agonomico de Campinas, Campinas, Brazil

³Department of Agriculture and Fisheries, Brisbane, Australia

⁴Department of Agriculture and Fisheries, Tully, Australia

⁵Institute of Fruit Tree Research, Guangdong, China

⁶Bioversity International, Yunnan, China

⁷Bioversity International, Montpellier, France

⁸Stellenbosch University, Stellenbosch, South Africa

Subtropically-grown bananas have differential interactions to *Fusarium oxysporum* f. sp. *cubense* (Foc), causal agent of Fusarium wilt (FW), when compared with bananas grown in the tropics. The designation 'subtropical' race 4 (SR4) was assigned to Foc strains able to infect Cavendish (AAA) cultivars in the subtropics, but not in the tropics. 'Tropical' race 4 (TR4) gained prominence with the appearance and spread of Foc strains that severely affect Cavendish bananas in both the tropics and subtropics. SR4 includes Vegetative Compatibility Groups (VCGs), 0120/15, 0122, 0129/11 and 01210, and TR4 includes VCG 01213/16. Recent surveys in Asia revealed 01213/16 as the predominant VCG both in the tropics and subtropics, affecting not only Cavendish, but also many other cultivars. In many subtropical banana zones, Foc race 1 and 2 (different VCGs), which complete the racial structure of Foc, are also found and cause severe losses in certain market-preferred dessert bananas. Environmental constraints are believed to influence the susceptibility of Cavendish banana to SR4. However, the role of abiotic stresses in cultivar susceptibility to FW is still poorly understood. It is not clear why only some Foc strains affect Cavendish in the subtropics and what other factors, including pathogen virulence and microbial functional diversity, might be driving disease epidemics. Field experience suggests that optimum soil and water management strategies can reduce disease intensity, but targeted studies are needed to understand the virulence of different VCGs under different inoculum levels, fluctuating temperatures and the interaction with soil organic matter breakdown and soil microbial dynamics. Research findings on the epidemiology and management of FW of banana in Australia, Brazil, China and South Africa will be discussed to propose priority areas for the development of improved disease management practices under conditions of increasing climatic variability.

Keywords: Epidemiology; *Fusarium oxysporum* f. sp. *cubense*, Panama disease



IDENTIFYING BANANA GENOTYPES RESISTANT TO FUSARIUM WILT RACE 1 UNDER FIELD AND GREENHOUSE CONDITIONS

Edson Amorim, Tamyres Rebouças, Fernando Haddad, Claudia Fortes Ferreira, Carlos Ledo and Vanusia Amorim

Embrapa Cassava and Fruits, Embrapa Avenue, Cruz Das Almas, Cruz Das Almas-Bahia, Brazil

The objectives of this work were to identify banana genotypes resistant to *Fusarium* race 1 wilt and to estimate the genetic diversity among these genotypes using SSR markers, with the goal of selecting parents for hybridization. The experiment was conducted in an outdoor area artificially infested with the pathogen and in a greenhouse with inoculated seedlings. For the environmental control tests, the genotypes were inoculated with 10 grams of inoculum (106 UFC mL^{-1}) distributed in four holes around the seedlings. Disease indices (DI) were calculated for the field and greenhouse experiments, and the area below the disease progress curve (AUDPC) was calculated for the greenhouse experiment. Genotypes resistant to *Fusarium* wilt race 1 were identified, including four diploids that can be used in crosses with elite susceptible cultivars. The correlation between the DI field and greenhouse data was 0.85 ($p \leq 0.001$), which allows us to infer about the efficiency of the early selection method. To the best of our knowledge, this is the first work that compares field and greenhouse methodologies to select genotypes resistant to the pathogen. The SSR markers detected genetic variability among the genotypes, which will contribute to improvement strategies to develop Foc resistant cultivars.

Keywords: Breeding, *Musa* spp., Panama disease, selection

HOST REACTION OF 'PAHANG' (*MUSA ACUMINATA* SSP. *MALACCENSIS*) TO *FUSARIUM OXYSPORUM* F. SP. *CUBENSE* TROPICAL RACE 4

Lei Zhang¹, Tingting Bai¹, Dong Zhang², Yunyue Wang³ and Weihua Tang² and Si-jun Zheng¹

¹2238 Beijing Road, Kunming, China

²300 Feng Lin Road, Shanghai, China

³650201 Kunming, Kunming, China

Fusarium wilt is a destructive disease of banana, caused by the fungus *Fusarium oxysporum* f. sp. *cubense* (Foc). This disease, and in particular the tropical race 4 (TR4) strain, continues to be a major constraint to banana production. Identifying reliable sources of resistance and unraveling the underlying resistance mechanisms is essential for banana breeding programs. To better understand the invasion and colonization of Foc TR4 in banana, we systematically investigated the spore germination process and further pathogen development in the roots and pseudostem of banana plantlets derived from in vitro propagation, by comparing the resistant wild genotype 'Pahang' (*Musa acuminata* ssp. *malaccensis*, accession ITC0619) and the highly susceptible cultivar 'Baxi' (AAA, Cavendish). To monitor the infection process, tested plantlets were inoculated with green fluorescent protein (GFP)-labeled Foc TR4. It was observed that the pathogen completed its life cycle within 24 hours in vitro under appropriate conditions. Through microscopic observation, we found that the spores attached to the root epidermis, root hairs, lateral roots and the wound, but the pathogen invaded the xylem vessels mainly via the wound. Upward intrusions into the corm along the xylem of roots were similar in the resistant 'Pahang' compared with the highly susceptible 'Baxi' under the wounded inoculation procedure. However, the amount of fungal biomass and necrosis in the corm was significantly lower in 'Pahang' than in 'Baxi' at 14 days post inoculation (dpi), indicating that Pahang could block further proliferation of the pathogen and express persistent resistance to Foc TR4. The result was further validated by evaluation of the disease severity after 4 weeks in the greenhouse and after 8 months in a field severely infected field with TR4. These results show that 'Pahang' is highly resistant to Foc TR4. The outcome will assist in elucidating the resistance mechanism of 'Pahang' using transcriptomic profiling in the next step of this research.

Keywords: Disease resistance, germplasm evaluation, green fluorescent protein (GFP), infection process, Panama disease, wild species



COMBATING FUSARIUM WILT BY BREEDING BANANA VARIETIES RESISTANT TO FOC TR4**Chunyu Li¹**, Gan-Jun Yi, Qiao-Song Yang, Sheng Ou and Guiming Deng

Guangdong Academy of Agricultural Sciences, No 80 of Dafeng 2 Street, Tianhe District, 510640 Guangzhou, China

Fusarium wilt is seriously threatening the sustainable development of banana industry in China. Breeding varieties with high resistance is a very effective way to control such notorious disease. We established an evaluation system based on the incidence index of the symptoms occurred inside the banana rhizome. Through using this system, we evaluated the resistance levels of the collected germplasm and the new varieties. Collaborating with Bioversity International, we confirmed that all of the 55 East African highland banana germplasm are highly resistant to *Foc* TR4, which could eliminate the panic caused by the spreading of *Foc* TR4 to Mozambique. Recently we released a new variety with very high resistance to *Foc* TR4 in the field, named "Zhongjiao No.9" which is obtained from our cross breeding work. Using the suspension cells of the main banana cultivars, we also established the physical and chemical mutagenesis breeding systems, and through this system we selected "Zhongjiao No.3 and No.4", which have moderate resistance or tolerance to *Foc* TR4. Besides, we also seek for improving the resistance through molecular breeding, and a Host Induced Gene Silencing (HIGS) system was developed, and two genes (ERG11 and 6) which are the targets of some fungicides were interfered. The RNAi plants showed high resistance to *Foc* TR4 in the greenhouse testing and in field also. Moreover, our research group also developed the CRISPR/Cas9 mediated gene editing technology for the first time in banana, and albino plants have obtained from target gene *MaPDS* editing, and some candidate susceptible genes in transcriptome data are now being studied. At present, several resistant varieties bred by our group have been widely extended in the growing regions where Fusarium wilt seriously occurred, which has a consequence of effectively alleviating the economic losses caused by this disease.

Keywords: Crossing, Fusarium wilt of banana, molecular breeding, resistance

A COMPREHENSIVE STRATEGY FOR PREVENTION AND CONTROL OF FUSARIUM WILT OF BANANA BASED ON RESISTANT/TOLERANT VARIETIES**Chunyu Li**, Gan-jun Yi, Sheng Ou, Guiming Deng and Qiao-Song Yang

Guangdong Academy of Agricultural Sciences, No 80 of Dafeng 2 Street, Tianhe District, 510640 Guangzhou, China

Fusarium wilt of banana is a devastating disease caused by the fungus *Fusarium oxysporum* f. sp. *cubense* (Foc). An effective future disease controlling strategy should serve dual roles, both improving host resistance and reducing *Foc* population size in the field. Our research group has bred a number of banana cultivars with resistance to tropical race 4 (TR4), the most virulent race of *Foc*, for example Cavendish banana cv 'Zhongjiao No 3' (AAA), 'Zhongjiao 4' (AAA) and 'Zhongjiao 6' (AAA). Experiments *in vitro* showed that root exudates from these resistant lines inhibited TR4 spore germination and hyphal growth. In addition, a field survey over a period of 4 years showed that these resistant cultivars limited *Foc* population size in the field. Furthermore, we investigated additional ways to control *Foc* including crop rotation, soil disinfection and biocontrol. The crop rotation involving Chinese leek or rice shows that compared to rice, Chinese leek inhibited or even completely destroyed *Foc* in soils. Soil disinfection using ammonium bicarbonate/lime significantly decreased the *Foc* population in top but not deep soils. Biocontrol applying fermented banana pseudostems with endophytic and antagonistic *Trichoderma* spp. with high cellulose activity in the field limited disease incidence and suppressed the pathogen. In conclusion, we evaluated the effect of several control measures on soil inoculum levels of Fusarium wilt in banana production regions in Guangdong province, China. We proposed a comprehensive disease control strategy integrating multiple measures including use of resistant banana cultivars, crop rotation with Chinese leek and reducing soil inoculum levels by biocontrol.

Keywords: Disease control, disease prevention, *Fusarium oxysporum* f. sp. *Cubense*

THE DEVELOPMENT OF AN ADVANCED IRRIGATION WATER TREATMENT FOR THE ERADICATION OF *FOC* TR4 FROM SURFACE WATER FOR CONTINUED COST-EFFECTIVE BANANA PLANTATION IRRIGATION

Lothar Trueggelmann¹, Aniwai F. Peñalosa¹, Erez Shalev² and Rani Fischer²

¹Unifrutti Tropical Philippines, Inc., Vice President, Biotechnology and Research, Propia St. cor. Juan Luminton St., 8700 Malaybalay-City, Bukidnon, Philippines

²Bloom Agro Ltd., 61 Robinson Rd., 12-03 Robinson Center, Singapore, Singapore

In regions where the epidemic of *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (*Foc* TR4) approaches the watershed, the intrusion of the disease by irrigation with surface water is a very serious threat to Cavendish plantations. Therefore, a pilot setup in Bukidnon, Mindanao, Philippines of an advanced irrigation water treatment system with an improved mechanical irrigation water filtration (25 micron) and a controlled injection of Calcium Hypochlorite as disinfectant was developed. Aiming to minimize the overall chlorine demand for disinfection, the effectiveness of the filter to improve water quality by reducing turbidity, TSS and COD was evaluated. A series of in vitro tests (2-Factorial Complete Randomized Design with three replications) with increasing chlorine concentrations (0.5 to 6ppm) were conducted in order to identify technically feasible contact times and corresponding residual chlorine concentration requirements for the safe destruction of *Foc* TR4 spores including Chlamydospores. A PCR confirmed *Foc* TR4 isolate was grown for over 29 days on Potato Dextrose Agar for spore production. Factor A simulated the Contact Time (A1: five minutes and A2: ten minutes). Factor B consisted of not inoculated and not treated water samples (B1), *Foc* TR4 inoculated water (1x10⁵cfu/ml) treated with two chlorine concentrations (B2 and B3), treated with 60ml/L "Biocit40 SL", known to be an effective disinfectant (B4), and an untreated absolute control (B5). Microbial growth was evaluated at 2, 4 and 6 days after spread plate. Calcium Hypochlorite concentrations of 2 to 3 ppm showed only reduced *Foc* TR4 colony growth, whereas 5 to 6 ppm consistently controlled *Foc* TR4 growths in all six repeated trials. Additionally the effectiveness of the system against *Ralstonia solanacearum* was confirmed. In a confirmatory greenhouse trials irrigation water with 20 ppm chlorine for six weeks old banana plantlets showed no negative effects after eight weeks due to chlorine.

Keywords: *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (*Foc* TR4), irrigation water disinfection, irrigation water treatment, *Ralstonia solanacearum*

MANAGEMENT OF FUSARIUM WILT OF BANANA IN THE SUBTROPICS OF SÃO PAULO, BRAZIL

Luiz Teixeira¹, Edson Nomura², Erval Damatto², Henrique Vieira³, Wilson Moraes², Fernando Haddad⁴, Charles Staver⁵ and Miguel Dita⁵

¹Soil and Environmental Resources Research Center - Agronomic Institute of Campinas-IAC, Brazil;

²Agency for Agribusiness Technology of São Paulo-APTA, Brazil;

³Embrapa Meio Ambiente, São Paulo, Brazil,

⁴Embrapa Mandioca e Fruticultura, Bahia, Brazil;

⁵Bioversity International, Montpellier, France

Fusarium wilt (FW) of banana is a serious constraint to the production of 'Prata' (Pome, AAB) and 'Maçã' (Silk, AAB) cultivars in Brazil. The spread of the disease in banana stands reduces mat density and profitability and the build-up of disease inoculum in the soil complicates replanting on the same land. Management practices focused on improving root and soil health have potential to slow the spread of FW and inoculum build-up and to increase productivity on current banana lands. Three treatments to improve root and soil health (L1, L2, L3) were compared to grower practices over three cropping cycles on a FW-infected area in the subtropics of São Paulo, Brazil. Tissue-culture plants of 'Prata Anã' (Pome, AAB) were planted with increased use of diverse practice - N and P sources, inoculation with *Trichoderma asperellum*, and application of compost and silicon. In L3, the most intensive, Ca(NO₃)₂ and thermophosphate were applied as sources of N and P, together with 1 t/ha/year of silicon and 17 t/ha of compost. Endophytes were applied at pre-planting in L3. L2 and L1 were quantitative variations of L3. Control plots follow local practices in the use of urea and superphosphate without application of compost, *Trichoderma* or silicon. FW incidence was evaluated fortnightly, starting at month six after planting until first bunch harvesting and



every 6 months thereafter. Regardless the treatment, first symptoms of FW were observed at 220 days after planting. FW progress rate was higher in the control treatment than in the treatments L3, L2 and L1. Incidence of FW after three crop cycles was significantly reduced in L1 treatment (15%) compared to control. Alternative treatments increased yield by 27% in relation to the control treatment. Further improvement of management practices and experimental layouts for in field evaluations of FW in banana are discussed.

Keywords: *Fusarium oxysporum* f.sp. *cubense*, *Musa* spp., Panama disease

EVALUATION OF DIFFERENT BANANA VARIETIES ON FUSARIUM WILT TR4 RESISTANCE BY PHENOTYPIC SYMPTOM AND REAL-TIME QUANTITATIVE PCR

Sheng-tao Xu, Ting-ting Bai, Lei Zhang, Hua-cai Fan, Pei-wen Yang, Ke-suo Yin, Li Zeng, Xun-dong Li, Zhi-xiang Guo, Bao-ming Yang, Yu-ling Huang, Yong-ping Li and **Si-jun Zheng**

2238 Beijing Road, Kunming, China

Fusarium wilt is one of the most crucial constrain factors for sustainable development of banana industry, developing a rapid evaluation methodology for TR4 resistance with different banana varieties in greenhouse will provide a basis of resistant variety screening and further variety improvement for TR4 resistance in the field trial. In order to identify resistant differences among tested materials against Fusarium wilt and screen the reliable resistant resources for future variety improvement, Baxi, Guijiao No.1 and our selected line Yunjiao No.1 were evaluated in the greenhouse by the disease index survey in leaf symptom and stem dissection, real-time quantitative PCR after inoculation with *Fusarium oxysporum* f. sp. *cubense* Tropic Race 4 (*Foc* TR4) wild isolate (15-1) to plant roots. The result showed that Yunjiao No.1 had the best performance among the three banana varieties at 25 and 45 days after pathogen inoculation in three experiments. The overall performance related to TR4 resistance from strong to weak was: Yunjiao No.1 > Guijiao No.1 > Baxi. The pathogen content of the inoculated soil had no significant difference among different banana varieties planted. The pathogen content in the corm of the Yunjiao No.1 was low and showed significant different from that in Baxi ($P < 0.05$), however, it showed no significant difference with that in Guijiao No. 1. By the rapid evaluation methodology for TR4 resistance with different banana varieties in greenhouse, we found Yunjiao No.1 had the best tolerance compared with the other two varieties, and it deserved field selecting.

Keywords: Banana, disease incidence, Fusarium wilt, real-time PCR

GAMMA IRRADIATION - A POTENTIAL TOOL FOR THE CREATION OF VARIABILITY AND SELECTION OF MUTANTS WITH FUSARIUM WILT RESISTANCE IN BANANA CV. RASTHALI (AAB, SILK)

Marimuthu Somasundram Saraswathi, Kannan Gandhi, Raman Thangavelu, Subbaraya Uma and T.R. Ganapathi

National Research Centre For Banana (ICAR), Thogmalai Road, Trichirappalli, Tamil Nadu, 620102, India

Development of improved banana varieties with resistance to biotic and abiotic stresses is the need of the hour as they are highly threatening banana production worldwide. Race 1 of Fusarium wilt is a serious threat to Rasthali (AAB, Silk) which is a choice variety grown in southern parts of India. Resistant gene introgression into such susceptible commercial varieties through conventional breeding methods is not feasible as they are both male and female sterile. In this context, induced mutagenesis combined with toxin based *in vitro* screening is used in the present investigation as they are viable alternative tool available for the development of fusarium wilt resistant cv. Rasthali. Embryogenic cell suspension (ECS) was used as the initial explant as it enables easy handling of large populations under controlled conditions and evades the problem of chimerism due to their single cell origin. ECS was irradiated with gamma rays at doses ranging from 5 to 50 Gy prior to embryo maturation and LD50 was determined as 35 Gy based on 50% Fresh Weight gain (FWG) over control, settled cell volume (SCV) and regeneration efficiency. The mutated cell after regeneration in the embryo maturation medium were germinated in medium containing toxins namely fusaric acid (0.1mM) and culture filtrate (6%). The germinated plants obtained after *in vitro* screening were hardened and subjected to pot screening. Results indicated that out of 950 plants subjected for pot screening, one was found to be resistant with no vascular discoloration and this putative resistant



mutant has been initiated *in vitro* for further multiplication and evaluation in sick plot and hot spot areas for conformity of resistance.

Keywords: Banana, embryogenic cell suspension, culture filtrate, fusaric acid, gamma irradiation, fusarium wilt resistance, mutagenesis

SESSION III: Sustainable, innovative seed and production systems

KEYNOTE

DIVERSITY IN THE SUBTROPICS

Matt Weinert¹, David Peasley² and André Drenth³

¹Department of Primary Industries, Wollongbar, New South Wales, Australia,

²Peasley Horticultural Services Pty Ltd, Murwillumbah, New South Wales, Australia

³University of Queensland, Brisbane, Queensland, Australia.

Growing bananas in the diverse range of climatic and geographic conditions of the subtropics has many challenges. Subtropical growing conditions include long periods of low temperatures and often lack of irrigation water resulting in low overall production and significant impacts on achieving consistent quality throughout the year. Environmental stresses also increase vulnerability to Panama disease. Cultivation on hill slopes is required to escape frosts, which limits mechanisation. In an open market where subtropical growers must compete with growers without such constraints is THE CHALLENGE.

Some of these challenges are likely to increase as the effects of climate change intensify. On the other hand, some of the existing advantages of subtropical banana production over tropical regions such as reduced pest and disease pressure may be maintained or enhanced in some regions in the subtropics.

Overcoming the consequences and constraints of climatic variability from season to season and changing climatic conditions in the longer term will require the development of new varieties to improve resilience in the production sector and also to meet the increasing demand for greater consumer choice. New opportunities for niche markets demanding new sweeter, smaller and cooking banana varieties are opening up due to tourism to Asia where travellers are exposed to exotic taste and cooking experiences of a wide array of local banana varieties as well as increased global migration creating new markets for varieties other than Cavendish in some parts of the developed world.

Keywords: Banana, climate change, climate variability, cold tolerance, disease resistance, Lady Finger, *Musa*, variety evaluation

FARMERS' WILLINGNESS TO PAY FOR DISEASE-SCREENED AND LABELLED CLEAN BANANA PLANTING MATERIALS IN UGANDA

Enoch Kikulwe¹, Christopher Sebatta², Stanslus Okurut², William Tinzaara¹ and Eldad Karamura¹

¹Bioversity International, Kampala, Uganda

²Dept. of Agribusiness Natural Res. Econ., Makerere University, Kampala, Uganda

One of the main reasons for the persistence and increased spread of banana *Xanthomonas* wilt (BXW) is that farmers keep using and recycling infected planting materials. Use of disease-free, clean planting materials has been identified and promoted as one of the most effective practices for the control of BXW. Despite its documented advantages, farmer adoption of the practice remains very low. To develop a commercial market for clean banana seed for sustainable distribution, it is important to understand farmers' willingness to pay for this seed.

Using conjoint choice experiments, price hedonic modelling and data from 326 randomly selected farmers, the study investigates farmers' willingness to pay (WTP) for disease-screened and labelled clean banana planting materials. Also, the study examined factors influencing farmers' seed purchasing behavior in traditional and emerging banana growing areas in Uganda. Results show heterogeneity in farmers' WTP.



Farmers are willing to pay more for tissue culture bananas than macro-propagated bananas and cleaned banana suckers. The study finds that farmers are willing to pay more for labelled than unlabeled banana seed. However, the prices that farmers were willing to pay for clean tissue culture and macro-propagated bananas were lower than their prevailing market prices, reflecting a significant structural market challenge. The results suggest that key factors, such as farmer sex, level of commercialization, price of the planting materials and farmer perceptions about the clean seed, influence farmers' WTP for clean banana planting materials. The findings will be essential to design strategies for sustainable distribution and promotion of quality planting materials of vegetatively-propagated crops.

Keywords: Conjoint choice experiments, macro-propagation, quality planting materials, tissue culture, vegetatively-propagated crops, *Xanthomonas Wilt*

DEVELOPMENT OF DIRECT REGENERATION PROTOCOL FOR MASS MULTIPLICATION OF BANANA CV. RASTHALI (AAB, SILK) USING IMMATURE FLORAL HANDS AS EXPLANTS

Marimuthu Somasundram Saraswathi, N. Kavitha, K.P. Sajith, M. Bathrinath, G. Kannan, Suthanthiram Backiyarani and Subbaraya Uma

ICAR-NRCB, Tiruchirappalli, India, Tiruchirappalli, Tamil Nadu, India, Tiruchirappalli, Tamil Nadu, 620102, India
The present investigation confirmed the use of immature male floral hands as a simple and efficient tool for mass propagation of bananas and plantains with minimal / zero risk of contamination as compared to shoot tips which are commonly employed by the tissue culture companies towards the production of disease free quality planting material. The immature male floral hands of cv. Rasthali were used as explants for direct regeneration. The male inflorescence with floral hands in whorl numbers ranging from 8 to 25 (outer to inner) were cultured on MS medium supplemented with different combinations of growth regulators like BAP, IAA, Picloram and kinetin. Earliest greening (14 days) and meristematic clump formation (24 days) was observed in MS medium supplemented with BAP alone. The number of meristematic clump formed per explant depends upon the size of the floral hands. MS medium along with BAP and IAA was found optimum for shoot regeneration. Maximum of 28 shoots were obtained from single meristematic clump. Then the well developed shoots were transferred to rooting medium containing MS medium with IBA, NAA and activated charcoal. The plantlets derived from male floral hands were found to be true to type as confirmed using ISSR markers. The explants were totally free from the problems of contamination and phenolic exudation which are the major obstacles under *in vitro* conditions.

Keywords: Direct Regeneration, Meristematic clump, male flower inflorescence, quality planting material

FIELD EVALUATION OF CONTROL OPTIONS AGAINST THE BANANA WEEVIL *COSMOPOLITES SORDIDUS* AND TERMITES *MICROTERMES* SPP. IN *MUSA* SPP.

Vincent Umeh and Daniel Onukwu

National Horticultural Research Institute, Idi-Ishin Jericho Reservation Area, Oyo State Ibadan, Nigeria

Soil insects such as the banana weevil *Cosmopolites sordidus* and termites are known to be of economic importance in banana production in many parts of Nigeria. Damage by these soil pests can lodge banana stands or retard growth and thus lead to low yields. To offer solutions to farmers, a trial was designed to test the efficacy of some control options against banana weevils and termites. Two banana cultivars were used namely dwarf Cavendish (AAA genotype) and 'Agbagba' (AAB, Plantain). Treatments included applications of neem (*Azadirachta indica*) oil, neem mulch, minimal application of the insecticide chlorpyrifos, paring and dipping in hot water, and the control. The 2 x 5 factorial trial was laid out in randomized complete block design with three replications. Insect numbers were monitored in 2012 and the ratoon crop of 2013. Significantly lower numbers of weevils and termites were observed in plots treated with neem or chlorpyrifos insecticide compared to the control in 2012 and 2013. Lower weevil numbers were observed in plots where paring + hot water dip were applied compared to the control in 2012; a similar result was observed in 2013 but only on Cavendish. Termite numbers were not significantly different between the control plots and those of paring + hot water treatment. The abundance of ants belonging to the Myrmicinae was negatively correlated with the banana weevil number. No correlation was observed between weevils and other ant



groups identified. Higher yields were obtained in the treated plots compared to the control. Weather effects on insect populations during the periods of the trial were discussed. The results indicated that naturally occurring principles from neem and simple cultural practice of paring and hot water treatment can reduce banana pests. This can be enhanced by predatory ants which are natural enemies of banana weevils.

Keywords: *Azadiraccta indica*, hot water dipping, mulch, paring, ratoon crop, split pseudostem traps

SUSTAINABLE MANAGEMENT OF BLACK SIGATOKA WITH BIOLOGICS: SERENADE AND SONATA

Albert Schirring¹ and Corina Lierzer² and **Rolf Christian Becker¹**

¹Bayer CropScience AG, Crop Strategy and Portfolio Management, Alfred-Nobel-Straße 50, 40789 Monheim, Germany

²Alfred Nobelstrasse 50, 40789 Monheim am Rhein, Germany

Given the increasing challenges to manage Black Sigatoka and export fruit to countries with strict Maximum Residue Limit (MRL) requirements, banana growers need customized agronomic solutions that allow them to produce a quality, marketable commodity in an affordable way. Serenade™ and Sonata™ are effective biological contact fungicides. When used on Sigatoka, both can extend the life of current synthetic chemistries by managing resistance and can reduce synthetic residues on exported crops while providing efficacy. Both products are intended to be integrated into conventional programs. Serenade is to be used as a mixing partner with systemic fungicides and offers the ability to be mixed directly together with synthetic chemistry which increases the flexibility for use in practical field situations. Sonata is for use solo in protectant applications, as an alternative to Mancozeb and Chlorothalonil. Since both products utilize multiple modes of action in unique ways, they can be used similarly to multi-site, contact fungicides with low risk of resistance development. Due to their status as being exempt from tolerance, both products are useful tools in increasing market accessibility, even in tight MRL environments. Incorporating agronomic solutions such as Serenade and Sonata into programs offers many benefits to an increasingly challenging crop in the market environment of modern times and should be strongly considered by growers looking to improve their sustainable Sigatoka management.

Keywords: Banana, Biologics, Black Sigatoka, Sustainability

DIGITAL FARMING SERVICE TO REDUCE CHEMICAL LOAD IN BANANA PLANTATION

Albert Schirring¹, Jose Manuel Dominguez² and **Rolf Christian Becker¹**

¹Bayer CropScience AG, Crop Strategy and Portfolio Management, Alfred-Nobel-Straße 50, 40789 Monheim, Germany

²Bosques de Escazu. Apto 404-B, Carrizal, Escazu, 51031000 San Jose, Costa Rica

The banana industry is dealing with a major phytosanitary challenge every day, because of the black leaf streak disease (BLSD) caused by *Pseudocercospora fijiensis* and other threats such as nematodes and weeds.

In the last decades, this situation required the continuous increase of chemical applications in the Ecuadorian banana production due to the increasing fungicide resistance of fungal pathogens. At the same time, banana farms faced a significant increase of labor costs.

To address these issues, we developed a novel digital farming service in banana plantations for disease management. The procedure starts with an agricultural drone flight to capture multispectral photos from a banana farm. Photogrammetry software transforms the acquired information into the Normalized Difference Vegetation Index (NDVI), compares it with previous benchmarks of Ecuadorian banana producers and delivers the basis for monitoring plant growth and examining crop health.

The information generated allows banana growers to better understand the general evolution of BLSD among the different farm lots (3-5 ha) and to identify the absence of plants, mainly related to physical overturn and nematodes. The drone-based diagnosis service helps improve on-farm decision making and enables a more efficient and sustainable use of resources and input factors in banana production.



With this diagnosis, service growers can design an integrated disease management program focusing on the identified critical spots and apply biological fungicides or low-impact nematicides in a way that is specific to the target and area. A new diagnostic flight after six months delivers information on program efficiency and general improvements in the orchard.

Keywords: Banana, Black Leaf Streak Disease Precision Agriculture, Farm Management, Sustainability

UNDERSTANDING GENDER ROLES AND PRACTICES IN INNOVATION PROCESSES: A CASE STUDY OF BANANA XANTHOMONAS WILT (BXW) DISEASE MANAGEMENT IN BURUNDI

François Iradukunda¹, Renee Bullock², Anne Rietveld³ and Boudy Van Schagen¹

¹Bioversity International, Bujumbura, Burundi

²IITA, Karambo office, Bukavu, Congo

³Bioversity International, Kampala, Uganda

Banana Xanthomonas Wilt (BXW) is a bacterial disease that threatens household income and food security in Burundi. Single disease stem removal (SDSR) is a new practice that has been introduced to improve BXW control. Gender inequality is known to influence women and men's access to, dissemination and utilization new agricultural innovations. We use a systems approach to better understand gender dimensions of innovation processes. We draw on qualitative data to describe the ways in which gender norms underpin roles and practices in banana-based farming systems that influence innovation processes and potential to scale new practices in the community.

Keywords: Banana Xanthomonas Wilt (BXW), Farmer Learning Groups, Gender, Innovation Processes, Single-diseased stem removal (SDSR)

INDUCTION OF SOMATIC EMBRYOGENESIS IN RECALCITRANT *MUSA* SPP. BY MEDIA MANIPULATION BASED ON THE MOLECULAR MECHANISM

Subbaraya Uma, Marimuthu Kumaravel, Suthanthiram Backiyarani, Somasundaram Marimuthu Saraswathi and Kumar Arun

ICAR- National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India, Tiruchirappalli, Tamil Nadu, 620102, India

Somatic embryogenesis (SE) is a high throughput technique for the large scale production of quality planting material, genetic transformation and mutation breeding. Although SE is well reported in selected banana varieties, most of the commercial cultivars are recalcitrant to SE. In order to induce SE in recalcitrant genotypes through media manipulation, knowledge on genes responsible for SE is of paramount importance. Our earlier studies on comparative proteomic profiling between embryogenic calli (EC) and non embryogenic calli / germinating and non germinating somatic embryo (se) of cv. Grand Naine (AAA), putative genes responsible for EC induction and germination of se have been identified. Thus based on the results of our earlier studies, callus induction media was manipulated in four recalcitrant cultivars with different genomes (Red Banana- AAA, Monthan- ABB, Karpooravalli- ABB and Neypoovan- AB) with one responsive cv. Grand Naine. In total 375 explants of each cultivar were initiated on different media combinations. After 5- 8 months of explant initiation, EC induction was recorded. In cv. Grand Naine, increased concentration of IAA recorded highest EC induction of 24.28 %, while Red Banana with similar genome showed 18.96 % in kinetin supplemented media. Similarly, in cultivars Monthan and Karpooravalli with ABB genome showed maximum EC induction in tryptophan supplemented media (8.54 %) and CaCl₂ enriched media (17.34 %) respectively. In cv. Neypoovan, higher concentration of tryptophan induced more EC (27.44 %). These results illustrated that EC formation in banana is not only genome dependent but also cultivar dependent. Simultaneously, germination media has been modified to induce the proteins responsible for germination of se. In cv. Grand Naine, media supplemented with 1 mg/L NAA and 0.5 mg/L GA₃ showed highest germination of 91.0 % whereas in cv. Rasthali, 10 mM CaCl₂ enriched media showed maximum germination of 91.2 %. Thus present study revealed that media augmentation based on proteomic studies can trigger EC in recalcitrant banana cultivars and germination efficiency in varieties showing better response for SE.



Keywords: Germination, embryogenic calli, proteomics, somatic embryo, somatic embryogenesis

SESSION IV: Post-harvest quality, use of banana waste, production costs and economics, smart marketing

KEYNOTE

SWEETER BANANA CO-OPERATIVE MARKETING

Doriana Mangili

Sweeter Banana Co-Operative, P.O. Box 567, Carnarvon WA 6701, Australia

Carnarvon is located 900 kilometres North of Perth, Western Australia, in the subtropics, on the edge of the desert. The climate results in a smaller, sweeter and tastier banana. Carnarvon supplied all Western Australia's bananas from the 1950's when the horticultural area was established until the 1980's when the tropical North Queensland bananas began to dominate the Australian Banana Industry. Queensland bananas are twice the size, golden and cleaner than the Carnarvon banana and became more popular with retailers. From the mid 1980's until the early 1990's demand for Carnarvon Bananas reduced until up to 60% of product was being discarded as it did not meet the increasingly rigid quality standards. Carnarvon bananas were not sold in major retailers; price was determined based on supply from Queensland, not Carnarvon, and sales were often at below the cost of production.

In 1993, Carnarvon growers, desperate to save their industry, founded The Sweeter Banana Co-Operative, owned by the farmers who grow on family-run properties. Initially established as a marketing group, the collaborative venture aimed to raise the profile of Carnarvon Bananas and regain market share. Through a range of measures including centralised packing, collaboration, improved quality, integration of the supply chain and investment in marketing initiatives the co-operative has been able to increase the sale price and farm gate return to growers, becoming the premium banana in Western Australia. The Carnarvon banana is now a differentiated product where price, whilst linked to the Queensland banana, is set based on local volumes. A range of initiatives has seen banana waste reduce from 60% to 5%.

The Carnarvon banana in 1993 was the banana no one wanted to buy, not stocked in major supermarkets. Today it is the premium banana product in Western Australia, consumers are willing to pay more for Carnarvon Bananas and they are sold at all major retail outlets. The presentation covers the history of the co-operative, the journey, vision, leadership, lessons learnt, marketing strategies, activities, achievements and future.

Keywords: Collaboration, co-operative, flavour, marketing, quality, supply chain integration, taste

GENDER ROLES AND CONSTRAINTS IN THE GREEN COOKING BANANA VALUE CHAIN: EVIDENCE FROM SOUTH WESTERN UGANDA

Susan Ajambo¹, Gloria Esther Mbabazi¹, Asha Nalunga² and Enoch Kikulwe¹

¹Bioversity International -Uganda, Plot 106, Katalima Road, Naguru, P.O Box 24384 Kampala Kampala, Uganda

²National Agricultural Reserach Organisation, Kampala, Uganda

This paper provides an overview of how women and men engage in the Matooke Value Chain (MVC) and the specific constraints they face. Several recommendations for gender-responsive interventions are made. Results are based on quantitative and qualitative data collected in 2015 in south western Uganda in the districts of Rakai and Isingiro under the EU/IFAD supported ENDURE project which aimed at reducing post-harvest losses and improving value addition in the MVC. Data were collected from actors along the value chain either by surveys, key informant interviews, Focus Group Discussions(FGD)s, seasonal calendars and daily activity schedules. Results show that women dominate in retail of Matooke (70%) with Average Profit Margins (APM) of \$1.4 and \$1.8 per bunch sold during scarcity and surplus production periods respectively but are absent in other services and sectors of the VC such as brokerage (APM of \$0.3 and \$0.6 per bunch sold in scarcity and surplus production periods respectively) and wholesale (APM of \$2.6 and \$1.05 per bunch sold in scarcity and surplus production periods respectively).



Production is controlled by men overseeing the Matooke plantation management and sales. Women are involved in various production activities such as weeding and de-budding. Some women also have their own plantations but acreage is usually smaller than for men. In addition, women are more constrained than men in accessing credit from financial institutions due to lack of collateral and they mostly rely on farmer's organizations for credit. The high commercialization of Matooke leading to continued expansion of Matooke plantations is putting pressure on land allocated to annual crops, which are mainly under the control of women. We recommend strengthening of farmer's organizations to increase women's access to credit; intensification and intercropping of Matooke systems; product differentiation and trainings tailored to the needs and priorities of men and women.

Keywords: Agricultural value chains, gender roles, green cooking banana, Matooke value chain, value chain analysis

DYNAMICS OF BANANA RESEARCH AND DEVELOPMENT IN INDIA FOR FARM PROFITABILITY ENHANCEMENT

Harishchandra Prasad Singh and Babita Singh

Confederation of Horticulture Associations (CHAI), 249, Sector 18A, Dwarka, 110078 New Delhi, India

India is the largest producer of banana in the world and assumes much greater significance in enhancing farmers' income besides providing nutrition to consumer. Total production of banana in India is 29.8 million tonnes from 0.85 million hectares and accounts for more than 35 percent share in total fruit production and contributes about 2.5 percent to the Agricultural Gross Domestic Product (AGDP) of the country. Dramatic change in the production of banana, from 6.5 million tons in 1991 to about 30 million tonnes currently is attributed to technological changes and improvement in value chain management. Government has provided focused attention and investment for the research and development of banana in the country by establishing National Research Centre for Banana, and through programs of National Horticulture Mission, which facilitates farmers to take up banana cultivation with improved techniques. A major private player for banana research and development in the country is Jain Irrigation Systems Limited, Jalgaon, Maharashtra, which produces about 750 million tissue cultured plants annually, assured with freedom from diseases, and is a largest producer of tissue cultured plants of banana in the world. They also provide technical support to the network of 5 million farmers and equipment for fertigation. Although India has provided leadership in production of banana but export has been limited, due to highly competitive export market. Now focus is on export and many companies in India are working for the export of banana from the country. The paper presents various facets and milestone of innovations which has led to transformation in banana production in India.

Keywords: Banana, India, national horticulture mission, technological changes, tissue cultured plants

