Asic
A unique source of information on coffee research



Hanoi VIETNAM

11-14 Sept. 2023 Melia Hanoi Hotel

BOOK OF ABSTRACTS

29th Conference

Asic 2023

Agronomy | Chemistry | Technology | Physiological effects

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PROGRAM AT A GLANCE

Agronomy I Chemistry I Technology I Physiological effects

Time*	MONDAY 11 SEPTEMBER	TUESDAY 12 SEPTEMBER
08:00	OPENING SESSION	SESSION 2 *Alvaro Gaitán* + Oral presentations
09:45		
10:00	Break	Break
10:15		
10:30	SESSION 8 *Devin Peterson* + Oral presentations	SESSION 5 *Jarrod Kath* + Oral presentations
12:00	Lunch	Lunch
13:30	SESSION 9 *Rob Van Dam* & *Peter M. Kistler* + Oral presentations	SESSION 8 Oral presentations
15:15		Break
15:45		
16:00	Break	SESSION 1 *Corné Pietersen* + Oral presentations
16:30	M1 - SESSION MISCELLANEOUS 1	
17:30		
18:00		ASIC BOARD MEETING
20:00		

* VIETNAM am = Asia am + America (J-1) 05-12 pm + Brazil 10-12 pm

VIETNAM pm = Asia pm + Africa/Europa am + Brazil 05-07 am

Session 1: Coffee plant science
Session 2: Plant Pathology & Protection
Session 3: Farm management
Session 4: Green coffee processing
Session 5: Climate change - Sustainability - Labels
Session 6: Biochemistry & Biotechnology of green coffee
Session 7: Roasted coffee Technology & Processing
Session 8: Coffee Chemistry & Sensory sciences
Session 9: Consumption-Health & Safety

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PROGRAM AT A GLANCE

Agronomy I Chemistry I Technology I Physiological effects

Time*	WEDNESDAY 13 SEPTEMBER	THURSDAY 14 SEPTEMBER
08:00	SESSION POSTER	SESSION 1 Oral presentations
09:45	Break	Break
10:15	SESSIONS 3 & 5 Oral presentations	M2 SESSION MISCELLANEOUS 2
12:00	Lunch	Lunch
13:30	SESSION 7 *Sebastian Opitz* + Oral presentations	SESSION 2 Oral presentations
15:15	Break	CLOSING SESSION
15:45		
16:00	SESSIONS 4 & 6 *Adriana Farah* + Oral presentations	16:00 - DEPARTURE AEROPORT 18:40 - VN1603 DEPART BUON MA THUOT
17:30	GENERAL ASSEMBLY	
18:30	19:00 - CONFERENCE DINNER	

* VIETNAM am = Asia am + America (J-1) 05-12 pm + Brazil 10-12 pm

VIETNAM pm = Asia pm + Africa/Europa am + Brazil 05-07 am

Session 1: Coffee plant science
Session 2: Plant Pathology & Protection
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KN: Keynotes **O:** Oral presentations

MONDAY 11 SEPTEMBER

08:00-10:00 **Opening Session**

Chairs: ***Astrid Nehlig & Benoît Bertrand***

- **Astrid Nehlig** - ASIC president
- **Dao The Anh** - LOC President
- **Andrea Illy** - Honorary President
  Regenerative agriculture and beyond in the coffee industry
- **Phan Viêt Hà** (WASI) **& Buy Quang Dang** (VAAS)
  Coffee industry in Vietnam

10:00-10:30 **Break**

Keynote lecturer & Oral presentations

10:30-12:00 **Session 8: Coffee Chemistry & Sensory sciences**

Chairs: ***Valérie Leloup & Rodrigo Cunha***

10:30-11:15
- **S8-KN - Coffee Chemistry: Aroma, Taste and Beyond**
  Devin Peterson *(Ohio State University, USA)*

11:15-11:45
- **S8-O-01 - A new Coffee Brewing Control Chart relating sensory properties and consumer liking to brew strength, extraction yield, and brew ratio**
  Guinard Jean-Xavier *(UC Davis Coffee Center, University of California, Davis, California, USA)*
- **S8-O-02 - Sensory Analysis of the Flavor Profile of Full Immersion Hot, Room Temperature, and Cold Brewed Coffee over Time - *Liang Jiexin*** *(UC Davis Coffee Center, University of California, Davis, California, USA)*
- **S8-O-03 - Alkyl furan formation in coffee - Role of precursors and impact of the roast degree on their origin**
  Poisson Luigi *(Nestlé PTC Beverage Orbe, Société Produits Nestlé SPN, Orbe, Switzerland)*

11:45-12:00
- **Questions / Answers**

12:00-13:30 **Lunch**

Keynote lecturers & Oral presentations

13:30-16:00 **Session 9: Consumption-Health & Safety**

Chairs: ***Astrid Nehlig & James Coughlin***

13:30-14:15
- **S9-KN-1 - Coffee consumption and risk of type 2 diabetes and cardiovascular diseases**
  Rob Van Dam *(The G. Washington University, USA)*

14:15-15:00
- **S9-KN-2 - Effects of regular coffee consumption on cardio vacular diseases: findings from the UK biobank**
  Peter Kistler *(Melbourne University, Australia)*

15:00-15:40
- **S9-O-01 - Coffee silverskin: A potential value-added by-product with similar effects as coffee on sugar metabolism**
  Barreto-Peixoto Juliana A. *(Laboratory of Bromatology and Hydrology, Department of Chemical Sciences, REQUIMTE/LAQV, Faculty of Pharmacy, University of Porto, Porto, Portugal)*
- **S9-O-02 - Combining netnography and means end chain analysis to research coffee brewing habits**
  Guinard Jean-Xavier *(UC Davis Coffee Center, University of California, Davis, California, USA)*
- **S9-O-03 - Influence of Roasting on Total Phenolic Content and Antioxidant Activity of Philippine Coffee**
  Mojica Ruel *(Cavite State University, Indang, Cavite, Philippines)*
- **S9-O-04 - Evaluation of taste and aroma of coffee and its relation to electroencephalography using emotion analyzer**
  Kakiuchi Misako *(R&D Department, UCC Ueshima Coffee Co., Ltd., Kobe, Hyogo, Japan)*

15:40-16:00
- **Questions / Answers**

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16:00-16:30 Break

Oral presentations

16:30-17:30 **Session M1: Miscellaneous 1**

Chairs: ***Kifle Belachew Bekele & Luu Ngoc Quyen***

16:30-17:10

- **M1-O-01 - The expansion of Geographical Indications on coffees: opportunities and challenges**
  Marie-Vivien Delphine *(Cirad, France)*
- **M1-O-02 - Smallholder-ready mobile pictures for coffee crop yield prediction**
  Rivera Palacio Juan Camilo *(Environment and Natural Sciences, Brandenburgische Technische Universität (BTU) Cottbus–Senftenberg, Cottbus, Germany)*
- **M1-O-03 - Microbial profiles of Brazilian *Coffea arabica* and *Coffea canephora***
  Louzada Pereira Lucas *(Coffee Design, Instituto Federal do Espírito Santo, Venda Nova do Imigrante, ES, Brazil)*
- **M1-O-04 - Economic Analysis of the Technical Efficiency and Profitability of Coffee Production in Kogi state, Nigeria**
  Orisasona Taiye *(Economics and Extension, Cocoa Research Institute of Nigeria, Ibadan, Nigeria)*

17:10-17:30

- **Questions / Answers**

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KN: Keynotes **O:** Oral presentations

TUESDAY 12 SEPTEMBER

Keynote lecturer & Oral presentations

08:00-09:45 **Session 2: Plant Pathology & Protection**

Chairs: ***Maria de Ceu Silva & TBC***

08:00-08:45
- **S2-KN - Overcoming pests,diseases and climate variability: the tale of Colombian coffee**
  Gaitán Alvaro *(Cenicafé, Federación Nacional de Cafeteros, Manizales, Caldas, Colombia)*

08:45-09:25
- **S2-O-01 - A chromosome-level genome resource for studying virulence mechanisms and evolution of the coffee rust pathogen *Hemileia vastatrix***
  Tobias Peri *(The University of Sydney, Camperdown, NSW, Australia)*
- **S2-O-02 - BRE4: Advancing Sustainable Coffee Plantations with a Cost-Effective Bionematicide**
  Asyiah Iis Nur *(Biology Education, Universitas Jember, Jember, East Java, Indonesia)*
- **S2-O-03 - Climate change and its impact on economically important coffee diseases in India**
  Sudha Muniswami *(Central Coffee Research Institute, Plant Pathology Division, Coffee Board of India, Chikkamagaluru, Karnataka, India)*
- **S2-O-04 - Can commercial bioinoculants available on the market in Vietnam protect coffee seedlings from *Meloidogyne incognita* infestation under controlled conditions?**
  Nguyen Van Long *(School of Life and Environmental Sciences, Deakin University, Melbourne, Victoria, Australia)*

09:25-09:45
- **Questions / Answers**

09:45-10:15 **Break**

Keynote lecturers & Oral presentations

10:15-12:00 **Session 5: Climate change - Sustainability - Labels**

Chairs: ***Philippe Vaast & Dao The Anh***

10:15-11:00
- **S5-KN - Integrating climate risk management and insurance for sustainable coffee production in a changing climate**
  Kath Jarrod *(School of Agriculture and Environmental Science, University of Southern Queensland, Toowoomba, QLD, Australia)*

11:00-11:40
- **S5-O-01 - Coffee system archetypes to prioritize decarbonization and regenerative agriculture practices**
  van Asten Piet *(ofi (Olam Food Ingredients), Singapore, Singapore)*
- **S5-O-02 - Using farmer knowledge to promote suitable shade tree species with ShadeTreeAdvice**
  Rigal Clément *(UMR Absys, CIRAD, Montpellier, France)*
- **S5-O-03 - Detecting deforestation in Vietnam coffee growing regions**
  Browning David *(Enveritas Inc, Old Greenwich, Connecticut, USA)*
- **S5-O-04 - Innovative strategies to attract youth and women participation in the coffee value chain in Tanzania**
  Jeremiah Magesa Marco *(Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania)*

11:40-12:00
- **Questions / Answers**

12:00-13:30 **Lunch**

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Oral presentations

13:30-15:15 **Session 8: Coffee Chemistry & Sensory sciences**

Chairs: ***Sebastian Opitz & Jean-Xavier Guinard***

13:30-14:10
- **S8-O-04 - New insights into the complex world of coffee flavour chemistry**
  Fisk Ian *(International Flavour Research Centre, University of Nottingham, Loughborough, Leicestershire, United Kingdom)*
- **S8-O-05 - Smart on-line coffee roasting process control by MassSpectrometry: Real-Time prediction model for coffee-roasting degree, brew antioxidant capacity and sensory attributes**
  Zimmermann Ralf *(Chair of Analytical Chemistry, University of Rostock, Rostock, Germany)*
- **S8-O-06 - The chemistry behind the coffee flavour evolution over time: an omicapproach**
  Liberto Erica *(Dipartimento di Scienza e Tecnologia del Farmaco, Università degli Studi di Torino, Torino, Italy)*
- **S8-O-07 - Sensory and metabolic profiles of Coffea canephora accessions from DR Congo**
  Bollen Robrecht *(Meise Botanic Garden, Meise, Belgium)*

14:10-14:30
- **Questions / Answers**

14:30-15:00
- **S8-O-08 - Home-brewed coffee - The influence of temperature, flow and grind size on aroma composition of espresso coffee**
  Cleve Nina *(Department of Sensory Analytics and Technologies, Fraunhofer Institute for Process Engineering and Packaging IVV, Freising, Germany)*
- **S8-O-09 - Influencing Espresso bitterness and sourness based on extraction kinetics**
  Schmieder Benedikt *(Biothermodynamics, Technical University Munich, Freising, Germany)*
- **S8-O-10 - Model-Based Prediction of Espresso Taste – Brewing Control Chart for Varying Flow Rate, Temperature, and Coffee to Water Ratio**
  Briesen Heiko *(Process Systems Engineering, TU Munich, Freising, Germany)*

15:00-15:15
- **Questions / Answers**

09:45-10:15 Break

Keynote lecturer & Oral presentations

15:45-17:30 **Session 1: Coffee plant science**

Chairs: ***Benoît Bertrand & TBC***

15:45-16:30
- **S1-KN - Root microbiota and induced systemic resistance**
  Corné Pietersen *(Utrecht, The Netherlands)*

16:30-17:10
- **S1-O-01 - Arbuscular Mycorrhizal Fungi (AMF) Associations of Robusta Coffee** *(Coffea canephora)* **across a Management Intensity Gradient in the DR Congo using Illumina Sequencing**
  Broeckhoven Ieben *(Dep. of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium)*
- **S1-O-02 - Selection for high yield, cup-quality and bean composition in coffee using Multi-trait Genotype-Ideotype Distance Index**
  Aberkane Hafid *(Nestle Institute for agricultural sciences, Plant science unit, Notre-Dame-d'Oé, France)*
- **S1-O-03 - Transcriptional control of the endosperm maturation program and galactomannan cell wall deposition in *Coffea* species**
  Joët Thierry *(DIADE, IRD, Montpellier, France)*
- **S1-O-04 - Genetic diversity and structure of *Coffea arabica* and *Coffea racemosa* in Mozambique**
  Tapaça Inocência da Piedade Ernesto *(Instituto Superior de Agronomia, Lisbon, Portugal, Lisbon)*

17:10-17:30
- **Questions / Answers**

18:00-20:00 **ASIC Board meeting**

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KN: Keynotes **O:** Oral presentations

WEDNESDAY 13 SEPTEMBER

Poster presentations

08:00-09:45 **Session Poster**

09:45-10:15 Break

Oral presentations

10:15-12:00 **Sessions 3 & 5**

Chairs: ***Piet van Asten & TBC***

Session 5: Climate change - Sustainability - Labels

10:15-10:55

- **S5-O-05 - Results of a TEEB AgriFood project evaluating the sustainability of public policy scenarios in the coffee sector in Mexico**
  Manson Robert *(Functional Ecology Network, Instituto de Ecología, A.C., Xalapa, Veracruz, Mexico)*
- **S5-O-06 - 'Beyond the chain': landscape approaches to sustainability in the coffee sector**
  Neilson Jeffrey *(University of Sydney, Darlington, NSW, Australia)*
- **S5-O-07 - What roles sustainability standards and programs play in coffee Robusta smallholders' capacity to harness the shift to quality in Vietnam?**
  Tran Thi Minh Ngoc *(International Centre for Research in Agroforestry (ICRAF), Hanoi, Vietnam)*
- **S5-O-08 - Connecting Geographical Indication (GI) and sustainable practices with Hindu Philosophy Tri Hita Karana in the island of Bali**
  Fabianus Reza *(National Coop, Ministry of Cooperatives & SMEs Republic of Indonesia, Jakarta, DKI Jakarta, Indonesia)*

10:55-11:15

- **Questions / Answers**

Session 3: Farm management

11:15-11:45

- **S3-O-01 - Evaluating water requirements of Robusta coffee trees to reduce irrigation**
  Rigal Clément *(UMR Absys, CIRAD, Montpellier, France)*
- **S3-O-02 - Contrasted agronomical and physiological responses of five *Coffea arabica* genotypes under soil water deficit in the field in Northwest of Vietnam**
  Sarzynski Thuan *(DIADE, CIRAD, Ho Chi Minh, Vietnam)*
- **S3-O-03 - Root traits and biomass productions of drought resistant and susceptible arabica coffee varieties growing under contrasting watering regimes**
  Adem Mohammed Worku *(Deparment of Horticulture and Plant Sciences, Jimma University, Jimma, Ethiopia)*

11:45-12:00

- **Questions / Answers**

12:00-13:30 Lunch

Keynote lecturers & Oral presentations

13:30-15:15 **Session 7: Roasted coffee Technology & Processing**

Chairs: ***Robert Farr & TBC***

13:30-14:15

- **S7-KN - Expanding the flavour space of coffee: Impact of Species, Processing and Roasting**
  Opitz Sebastian E. W. *(Analytical Chemistry unit and Coffee Excellence Center, Zurich University of Applied Sciences, Waedenswil, Switzerland)*

14:15-14:55

- **S7-O-01 - Controllability of the coffee roasting process**
  Botha Cila *(School of Chemical and Minerals Engineering, North-West University, Potchefstroom, South Africa)*

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- **S7-O-02 - Physical and Chemical Responses of Robusta Coffee Beans to Superheated Steam Roasting**
  Severini Carla *(Department DAFNE - Lab of Emerging Technology and Food Formulation, University of Foggia, Foggia, Italy)*
- **S7-O-03 - Digital Twin-Assisted Optimization of the Coffee Roasting Process**
  Tück Sebastian *(Research and Innovation, PROBAT AG, Emmerich am Rhein, Germany)*
- **S7-O-04 - A new rugged photoionization mass spectrometer for on-line process analysis in industrial coffee roasting**
  Zimmermann Ralf *(Chair of Analytical Chemistry, University of Rostock, Rostock, Germany)*

14:55-15:15 • **Questions / Answers**

15:15-15:45 Break

Keynote lecturer & Oral presentations

15:45-17:30 **Sessions 4 & 6**

Chairs: ***Luciano Navarini & Heiko Briesen***

Session 6: Biochemistry & Biotechnology of green coffee

15:45-16:30 • **S6-KN - Transmuting coffee by-products into eatable and non-eatable products**
Adriana Farah *(Rio, Brazil)*

16:30-17:10 • **S6-O-01 - Prevalence of mycotoxigenic fungi and Ochratoxin A in green coffee beans (*Coffea arabica* L.)**
Hagos Legese *(Ethiopian Institute of Agricultural Research, Addis Abeba, Ethiopia)*

- **S6-O-02 - Coffee pulp byproduct – stabilization and characterization for a potential economic boost as a source of carbohydrates**
  Passos Cláudia P. *(LAQV/REQUIMTE, Department of Chemistry, University of Aveiro, Aveiro, Portugal)*
- **S6-O-03 - Oligosaccharides and Cyclitols derivatives in green *Coffea arabica* from different geographical origins**
  De Angelis Elisabetta *(Aromalab AREA Science Park, illycaffè spa, Trieste, Italy)*

Session 4: Green coffee processing

- **S4-O-01 - Comparative evaluation of effect of processing methods on coffee quality at Jimma, Ethiopia**
  Banti Misgana *(Food Science and Nutrition Research Directorate, Ethiopian Institute of Agricultural Research, Addis Ababa, Oromia, Ethiopia)*

17:10-17:30 • **Questions / Answers**

17:30-18:30 **ASIC General Assembly**

19:00 **Conference Dinner**

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KN: Keynotes **O:** Oral presentations

THURSDAY 14 SEPTEMBER

Oral presentations

08:00-09:45 **Session 1: Coffee plant science**

Chairs: ***André Charrier & Hafid Aberkane***

08:00-08:40
- **S1-O-05 - Leaf sugar metabolomic profiling reveals differences between *Coffea arabica* cultivars in two locations of Cerrado Mineiro (Brazil)**
  Campos Carréra Jéfyne *(Departamento de Biologia, Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil)*
- **S1-O-06 - Genome-wide association study identified SNPs and genes related to *Meloidogyne paranaensis* resistance in *Coffea arabica***
  Pereira Luiz Filipe *(Plant Biotechnology Lab, Instituto de Desenvolvimento Rural do Paraná, Londrina, PR, Brazil)*
- **S1-O-07 - The Innovea Global Coffee Breeding Network**
  Humphrey Tania *(World Coffee Research, Portland, Oregon, USA)*
- **S1-O-08 - Genetic diversity of *Coffea arabica*: significant update for its conservation and optimal use for breeding**
  Montagnon Christophe *(RD2 Vision, Valflaunes, France)*

08:40-09:00
- **Questions / Answers**

09:00-09:30
- **S1-O-09 - Heterosis in F1 Arabica hybrids and its use under different agronomic conditions**
  Bertrand Benoît *(DIADE/COFFEEADAPT/BIOS, CIRAD, Matagalpa, Nicaragua)*
- **S1-O-10 - Heterosis Breeding: A prospective strategy for Arabica coffee improvement in India**
  Das Divya Kallingapuram *(Plant Breeding and Genetics, Central Coffee Research Institute, Chikkamagaluru, Karnataka, India)*
- **S1-O-11 - The Democratic Republic of the Congo, the cradle of cultivated Robusta coffee *(Coffea canephora)*, can we safeguard its coffee genetic resources of world importance?**
  Stoffelen Piet *(Meise Botanic Garden, Meise, Belgium)*

09:30-09:45
- **Questions / Answers**

09:45-10:15 **Break**

Oral presentations

10:15-12:00 **Session M2: Miscellaneous 2**

Chairs: ***Chahan Yeretzian & Luigi Poisson***

10:15-10:55
- **M2-O-01 - New methodology to calculate the caloric value of traditional espresso coffee: bridging the gap between legislation and coffee chemistry**
  Navarini Luciano *(illycaffè spa, Trieste, Italy)*
- **M2-O-02 - Flavor Components of Coffee Beans Analyzed by headspace solid-phase microextraction / gas chromatography-mass spectrometry and Electronic Sensor Techniques**
  Chen Zhenjia *(Coffee sciences, Coffee engineering research center of China, Mangs, PR China)*
- **M2-O-03 - Influence of fuel types on roasting results and sustainability**
  Koziorowski Thomas *(R&D, Probat AG, Emmerich am Rhein, Germany)*
- **M2-O-04 - Zero Discharge Water Treatment at Coffee Wet Mill**
  Perotti Ermanno *(Upstream and Global Origins Innovation, Sucafina, Ho Chi Minh - Rieti, Vietnam)*

10:55-11:15
- **Questions / Answers**

11:15-11:45
- **M2-O-05 - Species and Geographical Origin Authentication of Philippine Coffee using XRF-based Multi-element and Stable Isotope Ratio Profiling Combined with Chemometric tools**
  Tan Kevin Neil *(Chemistry Department, De La Salle University, Manila, Philippines)*

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- **M2-O-06 - Variability and association between biochimical constituents and organoleptic quality attributing traits in Ethiopian coffee (*Coffea arabica* L.) accessions**
  Weldemichael Getachew *(Coffe and tea research program, EThiopian Institute of Agricultural Research, Jimma, Oromiya, Ethiopia)*
- **M2-O-07 - Genetic Variation Among Coffee Berry Borer (CBB) Localities in Jamaica**
  Myrie Ameka *(University of Regensburg, Regensburg, Germany)*

11:45-12:00 • **Questions / Answers**

12:00-13:30 Lunch

Oral presentations

13:30-15:15 **Session 2: Plant Pathology & Protection**

Chairs: ***Alvaro Gaitàn & Nayani Prakash***

13:30-14:10
- **S2-O-05 - Integrative transcriptomic and metabolomic approaches to unravel the resistance profile of Kawisari coffee against *Hemileia vastatrix***
  Silva Maria do Céu *(CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Universidade de Lisboa, Instituto Superior de Agronomia, Oeiras, Portugal)*
- **S2-O-06 - Diversity and Antagonistic Potential of Mycoparasites on Coffee Leaf Rust *Hemileia vastatrix* in Ethiopia**
  Bekele Kifle Belachew *(Plant Protection Department of Coffee Pathology Section, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia)*
- **S2-O-07 - Coffee berry disease: a century old anthracnose of green berries of Arabica coffee (*Coffea arabica* L.) in Africa**
  Adugna Girma *(Horticulture and Plant Sciences, Jimma University, Jimma, Ethiopia)*
- **S2-O-08 - Field performance of Arabica coffee genotypes for growth traits, yield, bean quality and disease tolerance**
  Aluka Pauline *(Coffee Cocoa Variety Improvement and Management, National Coffee Cocoa Research Institute (NaCORI), Mukono, NA, Uganda)*

14:10-14:30 • **Questions / Answers**

14:30-15:00
- **S2-O-09 - First report of a genome sequence resource of *Colletotrichum kahawae*, the causal agent of coffee berry disease**
  Azinheira Helena *(Instituto Superior de Agronomia, Lisbon, Portugal)*
- **S2-O-10 - Diversity and Dynamics of Fungal Endophytes in Coffee: Implications for Plant Health and Agriculture**
  Castillo Gonzalez Humberto *(Department of Plant Science and Landscape Architecture, University of Maryland, College Park, Maryland, USA)*
- **S2-O-11 - Potential association of HCF164, a chloroplast nuclear-encoded thioredoxin-like protein, with *Coffea* SH9 resistance factor against *Hemileia vastatrix***
  Guerra-Guimarães Leonor *(CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal)*

15:00-15:15 • **Questions / Answers**

15:15-15:45 **Closing Session**

Chairs: ***Astrid Nehlig & Benoît Bertrand***

16:00 **Departure to Buon Ma Thuot**

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CONFERENCE FIELD TRIP TO BUON MA THUOT

Buon Ma Thuot - The Metropolis of Coffee of Vietnam

Thursday 14 September 2023 - Day 4

Noi Bai airport to Buon Me Thuot airport

19:20 • Flight from **Hanoi City to Buon Me Thuot City**

21:05 **Buon Me Thuot City**

• Have dinner at the local restaurant

Muong Thanh Luxury Buon Ma Thuat Hotel 5*

21:30 • Check-in to your hotel

Friday 15 September 2023 - Day 5

Muong Thanh Luxury Buon Ma Thuat Hotel 5*

07:00 • Have breakfast at the hotel

The Western Highlands Agro-Forestry Scientific and Technical Institute

08:00-11:30 • Visit the **Western Highlands Agriculture and Forestry Science Institute (WASI)** and the coffee field in Buon Ma Thuot City

• Visit a coffee household and the **Eatu Coffee Cooperative factory** to see their coffee-making process from harvest to final products for export. Enjoy a coffee drink.

Buon Me Thuot City

11:30 • Have lunch at a local restaurant

Sightsee in Buon Ma Thuot City with the following schedule

13:00-17:00 • Visit the **Ethnographic Museum**

• Visit the **World Coffee Museum** by Trung Nguyen Legend – the biggest coffee producer in Vietnam

Muong Thanh Luxury Buon Ma Thuat Hotel 5*

17:00 • Travel back to the hotel

Buon Me Thuot City

19:00 • Have dinner at a local restaurant

21:00 • Enjoy personal activities

Saturday 16 September 2023 - Day 6

Muong Thanh Luxury Buon Ma Thuat Hotel 5*

07:00 • Have breakfast at the hotel

TBA

08:00-11:00 • Visit a **local coffee-processing Farm**

11:30-13:00 • Enjoy personal activities

Buon Ma Thuot Airport to Noi Bai Airport / Tan Son Nhat Airport

15:00 • Depart to **Buon Ma Thuat Airport for flight to Hanoi City or Ho Chi Minh City** - End of the trip

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ABSTRACTS MONDAY 11 SEPTEMBER

KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 8:
Coffee Chemistry & Sensory sciences

S8-KN

Keynote lecturer

Coffee Chemistry: Aroma, Taste, and Beyond

Peterson Devin (peterson.892@osu.edu)

Food Science and Technology, The Ohio State University, Columbus, OH, USA

Pursuing high-quality coffee involves various factors that positively contribute to the overall flavor experience. This presentation focuses on the molecular underpinnings of the flavor attributes, including aroma, taste, and somatosensations. A novel nontargeted flavoromics approach was used to study the volatile and nonvolatile chemical compounds that impact coffee quality, including cupping scores, bitterness, cold brew liking, and RTD flavor stability. Additionally, compounds contributing to coffee body/mouthfeel and the influence of cross-model taste-aroma interactions were investigated. Nonvolatile flavor compounds and novel modulators were identified that influence coffee quality and bitterness, impacting cupping scores and cupping profiles. Volatile compound compositions that were related to consumer preference were defined. Furthermore, small molecule nonvolatile compounds were also reported to enhance coffee flavor tactile perceptions. These findings advance our understanding of the complex chemical stimuli and mechanisms underlying coffee quality.

References:

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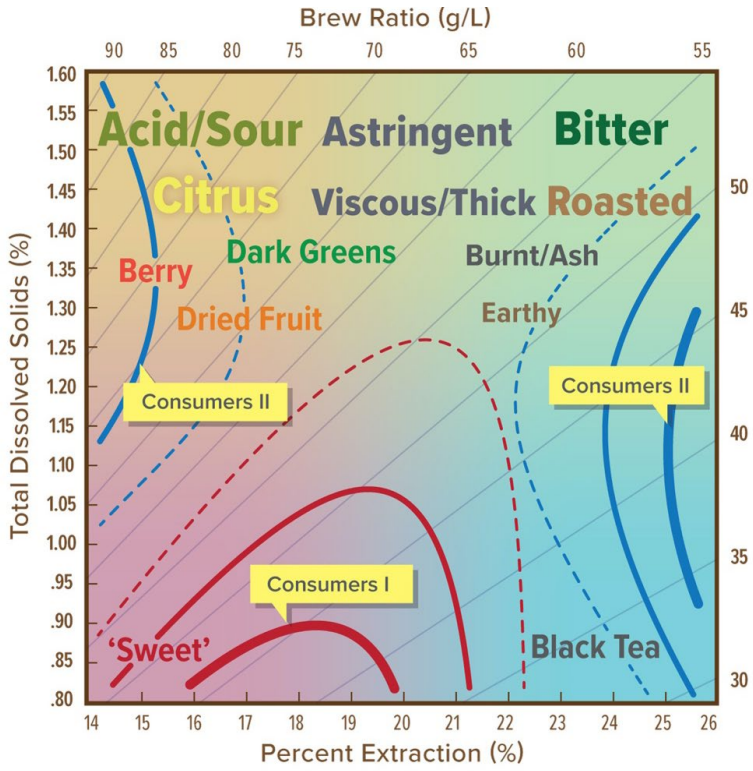
S8-O-01

A new Coffee Brewing Control Chart relating sensory properties and consumer liking to brew strength, extraction yield, and brew ratio

Guinard Jean-Xavier (jxguinard@ucdavis.edu), Frost Scott, Batali Mackenzie, Cotter Andrew, Lim Lik Xian, Ristenpart William

UC Davis Coffee Center, University of California, Davis, Davis, California, USA

The classic Coffee Brewing Control Chart (BCC) was originally developed in the 1950s. It relates coffee quality to brew strength and extraction yield, and it is still widely used today by coffee industry professionals around the world to provide guidance on the brewing of coffee. Despite its popularity, recent experimental studies have revealed that sensory attributes and consumer preferences actually follow much more complicated trends than indicated by the classic BCC. Here we present a methodology to synthesize the results of these recent studies on drip brewed coffee to generate new versions of the BCC: a new Sensory BCC that displays a broad array of statistically significant sensory attributes across typical total dissolved solids (TDS) and percent extraction (PE) ranges, a new Consumer BCC that highlights the existence of two preference clusters with different likes and dislikes across those ranges, a new Sensory and Consumer BCC that combines both sensory descriptive and consumer preferences on the same chart, and a more streamlined BCC that omits consumer preferences and focuses on the overarching sensory descriptive trends.



The New Sensory and Consumer Brewing Control Chart showing both key coffee sensory attributes and the response surfaces of two consumer preference segments (Consumers I and Consumers II) as a function of TDS, PE and Brew Ratio.

References:

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S8-O-02

Sensory Analysis of the Flavor Profile of Full Immersion Hot, Room Temperature, and Cold Brewed Coffee over Time

Liang Jiexin (jxliang@ucdavis.edu), Batali Mackenzie, Routt Catherine, Ristenpart William, Guinard Jean-Xavier

UC Davis Coffee Center, University of California, Davis, Davis, CA, USA

With the growing popularity of cold brewed coffee comes a need for efficiency while preserving the desirable flavor profile. Despite the wide use of full immersion brewing techniques, the effect of brew time on the dynamic sensory profiles of full immersion brewed coffee remains underexplored. Here, we investigated the relationship between coffee sensory quality and extraction dynamics, measured in Total Dissolved Solids (TDS) and Extraction (E) of full immersion brewed coffee under various roast level, brewing temperature (4°C, 22°C and 92°C), and brew time using a generic descriptive analysis method. Furthermore, the unique experimental design also explored a sensory-driven engineering research process. Since coffee extraction kinetics varies by temperature, different brew times were selected for different temperatures based on five targeted coffee extraction stages, which were utilized in multiple factor analysis (MFA) of the descriptive data.
Roast level had the greatest impact on the sensory profile of the coffees, followed by brewing temperature, but the effect of brew time was not pronounced. 25 of 28 sensory attributes were significantly different among the 30 coffee samples, indicating a single source green coffee blend can produce a wide range of complex sensory profiles using different combinations of roast level, temperature, and brew time. Specifically, the intensities of sweet and floral were negatively correlated with TDS, and all other significant attribute intensities were positively correlated with TDS. Interestingly, we found that that certain long time cold brews had similar sensory profiles to those of some short time hot brews based on the coffee we tested, suggesting the sensory profiles of certain hot brews and cold brews could possibly overlap through controlled preparation method. Overall, our study demonstrated an approach of integrating food engineering and sensory analysis for product development, and our findings provide valuable insights into the extraction dynamics and sensory quality of full immersion brewed coffee and brings new brewing avenues for the coffee industry.

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S8-O-03

Alkyl furan formation in coffee - Role of precursors and impact of the roast degree on their origin

Poisson Luigi (luigi.poisson@rdor.nestle.com), Davidek Tomas, Schaerer Ania

Nestlé PTC Beverage Orbe, Société Produits Nestlé SPN, Orbe, Switzerland

Rationale:
Next to furan, other alkyl furans such as 2- and 3-methylfuran (2-MF, 3-MF), 2-ethylfuran (2-EF), 2,5-dimethylfuran (2,5-DF), and 2-pentylfuran (2-PF) have been found in roasted coffee. Furan came into focus as a potent hepatotoxin and hepatocarcinogen in rodents and has been classified by the International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans (group 2B). Similar physiological effects are also debated for its derivative 2-methylfuran (2-MF).
While furan is well studied, less is known about the formation of other alkyl furans. Previous studies with model and real food systems showed that furan can be formed from multiple precursors such as saccharides, amino acids, polyunsaturated fatty acids, and ascorbic acid.1
Methods:
The role of sucrose and specific amino acids in the formation of several alkyl furans (2- and 3-MF, 2-EF, 2,5-DF, and 2-PF) upon coffee roasting was investigated in a kinetic study applying 13C- and 15N-labeled precursors in biomimetic in-bean experiments.*2*Analysis of volatiles was performed by Solid-Phase Microextraction−Gas Chromatography−Mass Spectrometry (SPME−GC−MS).
Results:
The formation kinetic for most of the alkyl furans was found similar to previously discussed furan and 2-MF. Their generation requests a high energy to start, consequently the formation kinetics shows a strong increase at the second half of the roasting course.
However, sucrose contribution to 3-MF, 2-EF, and 2,5-DF was more important as compared to furan and 2-MF. Sucrose and bound precursors contributed in comparable amounts to the formation of these alkyl furans along the whole roasting course. Whereas, for furan and 2-MF sucrose contributes only in the middle roasting stages, and main amounts of furan and 2-MF in the final product predominantly stem from other precursors (polysaccharides, lipids, etc.).
For 2-PF no contribution of sucrose was observed. The formation kinetic is also very different depicting a maximum reached at half-time, and a decline towards the end of roasting. These results are not surprising as 2-PF is a well-known degradation product of lipid oxidation.
Conclusions & Perspectives:
The combination of kinetic studies with labeling experiments in the coffee bean system was evidenced as a very powerful tool to elucidate the origin and possible formation pathways of furans upon coffee roasting. The results demonstrates that the formation of furan derivatives in coffee is very complex and closely interlinked with flavor formation. Hence, its mitigation is extremely challenging, mainly for dark roasted coffees to assure right sensory profile while avoiding other undesirable compounds such as acrylamide.

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KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 9:
Consumption-Health & Safety

S9-KN-1

Coffee consumption and risk of type 2 diabetes and cardiovascular diseases

Van Dam Rob (rvandam@gwu.edu)

Department of Exercise and Nutrition Sciences, George Washington University, Washington, District of Columbia, USA

A few decades ago, concerns were raised about the potential detrimental effects of coffee consumption on the risk of cardiovascular diseases and cancers. However, more thorough epidemiological studies suggest that these older findings were due to confounding by other behaviors such as smoking and by limitations of study designs. Findings from a large body of evidence from high-quality prospective cohort studies now indicate that coffee consumption is unlikely to have detrimental effects on chronic disease risk. In contrast, evidence has emerged that higher coffee consumption is associated with a lower risk of type 2 diabetes and cardiovascular diseases. Coffee is a major source of phytochemicals such as chlorogenic acid, caffeine, lignans, and trigonelline. Several of these compounds had beneficial effects on glucose metabolism in animal studies. However, the evidence from experimental studies in humans is more limited. Evidence is emerging that coffee consumption may reduce body fatness, and improve gut microbiota composition and liver insulin sensitivity. This presentation will discuss the current evidence on the effects of coffee consumption on cardiometabolic health and provide suggestions for further research.

S9-KN-2

Effects of regular coffee consumption on cardio vacular diseases: findings from the UK biobank

Peter Kistler

Melbourne University, Australia

S9-O-01

Coffee silverskin: A potential value-added by-product with similar effects as coffee on sugar metabolism

Barreto-Peixoto Juliana A.[1] (jpeixoto@ff.up.pt), Andrade Nelson[1,2], Machado Susana[3], Costa Anabela S.G.[1], Oliveira M. Beatriz P.P.[1], Martel Fátima[2,4], Alves Rita C.[1]

[1] *Laboratory of Bromatology and Hydrology, Department of Chemical Sciences, REQUIMTE/LAQV, Faculty of Pharmacy, University of Porto, Porto, Portugal* ; [2] *Department of Biomedicine – Unit of Biochemistry, Faculty of Medicine, University of Porto, Porto, Portugal* ; [3] *Laboratory of Bromatology and Hydrology, Department of Chemical Sciences, REQUIMTE/LAQV, Faculty of Pharmacy, University, Porto, Portugal* ; [4] *University of Porto, Instituto de Investigação e Inovação em Saúde (I3S), Porto, Portugal*

Rationale:
Coffee roasting industries generate around 7.5 kg of coffee silverskin (CS), the thin tegument that detaches from beans during the roasting process, per ton of roasted coffee.[1] This study aimed to ascertain the potential of CS to prevent type II diabetes, having in view its valorization, by comparing its properties with those of green (GC) and roasted coffee (RC), with benefits already known in this context.[2]

Methods:
Extracts of CS, GC and RC were prepared by aqueous ultrasound-assisted extraction and freeze-dried. Chorogenic acids (CGA) and caffeine contents were analyzed by RP-HPLC-DAD and the effects on the uptake of radioactive analogue of fructose (14C-fructose (14C-FRU) by human intestinal epithelial (Caco-2) cells were evaluated. The influence of the extracts on the expression of sugar transporter genes was also studied by RT-qPCR.[2]

Results:
CS extract (CSE) was the poorest regarding CGA and caffeine contents. In turn, the GC extract (GCE) was the richest in CGA, while RC one (RCE) showed higher contents of caffeine. Regarding the effect on 14C-FRU uptake, GCE was the most effective inhibitor, while RCE and CSE caused similar reductions, all significant (p<0.05). Finally, all extracts reduced gene expression of GLUT2 in a very markedly (p<0.05) and similarly way. None of them reduced the expression of the GLUT5 gene.

Conclusions & Perspectives:
Although CSE was not as rich in caffeine and CGA as the other samples, it was also able to significantly decrease 14C-FRU uptake in Caco-2 cells, with significant reductions in the mRNA expression levels of the GLUT2 transporter, which seems to justify the observed cellular effects. In sum, this study shows that CS might be as interesting as the coffee bean in preventing health disorders, namely type II diabetes, highlighting how it can be valued and integrated into circular economy scenarios.

Funding: This work was funded by the project PTDC/SAU-NUT/2165/2021- COBY4HEALTH, funded by Fundação para a Ciência e Tecnologia (FCT)/Ministério da Ciência, Tecnologia e Ensino Superior (MCTES), Portugal.
Acknowledgements: To FCT/MCTES for the projects UIDB/50006/2020 and UIDP/50006/2020, as well as UID/BIM/04293/2013 (to F.M.); to the European Union (FEDER funds through the NORTE2020-ref. NORTE-01-0145-FEDER-000041); to BICAFÉ for providing the samples. J.A.B.P. thanks to FCT/MCTES and ESF (European Social Fund) through NORTE 2020 for her PhD grant (SFRH/BD/07329/2021). N.A. and S.M. are grateful to the project PTDC/SAU-NUT/2165/2021 for their post-doc and research grants, respectively. R.C.A. thanks the FCT for funding through the Scientific Employment Stimulus—Individual Call (Ref. CEECIND/01120/2017).

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S9-O-02

Combining netnography and means end chain analysis to research coffee brewing habits

Guinard Jean-Xavier[1] (jxguinard@ucdavis.edu), Wong Jessica[2], Hernandez Ashley[1], Ashmore Maeve[1], Weber Angela[1], Palomo Andrea[3], Japara Monika[1], Lertsakulcharoen Sarinya[1], Magrath Samantha[1], Elliott Benjamin[1]

[1] *Department of Food Science and Technology, University of California, Davis, California, USA* ; [2] *Department of Nutrition, University of California, Davis, California, USA* ; [3] *University of California, Berkeley, California, USA*

Marketers have realized the value of researching human motivation in consumer behavior. We combined Netnography – the online observation of the consumer, and Means End Chain Analysis (MECA) to research the home brewing habits of coffee consumers. Trained teams of 2 or 3 observers/ interviewers observed 30 coffee consumers brewing their coffee at home using their customary or preferred method (i.e., drip brew, pour over, Aeropress, French press, espresso, capsules, etc.). They then interviewed them about their brewing method and habits using a laddering interview technique that opened with the question "Why do you use this method to brew your coffee?", and followed with a series of "Why is it important to you that…?" questions.

Netnography accessed critical innovation levers such as triggers of use (i.e., to wake up or as a break in the day), user customization (i.e., light or medium roasts preferred for full flavor expression and less bitterness; type of sweetener or creamer added if any), interactions with the user's environment (i.e., adjusting to local water composition), intangible attributes of the method (i.e., comfort from the brewed cup), and most importantly for breakthrough innovation - unarticulated user needs.

MECA produced a hierarchical value map that included caffeine, convenience, flavor, less wasteful, personalized, social drinking, and cheaper as the main attributes associated with consumers' brewing methods. Consequences of those methods were energy, saving time in the morning, pleasant aromatic properties, saving resources, controlling taste, desire to fit in, and saving money. In turn, MECA linked those consequences to such personal values as academic and career performance, enhanced productivity, enjoyment, environmental ethics, health consciousness, belonging, and financial responsibility.

This information can be used by coffee companies and manufacturers of coffee brewing equipment to optimize their offerings and design new brewing experiences.

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S9-O-03

Influence of Roasting on Total Phenolic Content and Antioxidant Activity of Philippine Coffee

Mojica Ruel[1] (ruelmojica@cvsu.edu.ph), Quirit Leni[2]

[1] *Cavite State University, Indang, Cavite, Philippines* ; [2] *University of the Philippines, Quezon City, Philippines*

Rationale:
Antioxidants which are found naturally in many foods and beverages, provide health benefits in preventing diseases such as heart disease and cancer by fighting cellular damage caused by free radicals in the body (Ramalakshmi et al., 2008). Few studies were made on the antioxidant activity of coffee in the Philippines. The study on the antioxidant activity of coffee will be useful in enhancing and promoting the competitiveness of Philippine coffee against imported varieties among local consumers and even the world market. The effect of roasting on the antioxidant activity level is also important particularly in the case of developing "coffee blends" that would give the highest beneficial effects without compromising the aroma and flavor.

Methods:
The phenolic content determination was based on a modified method by Rumbaoa (2008). The analysis of antioxidant activity was done on four coffee samples, namely: a) green coffee beans (unroasted beans); b) light roast beans; c) medium roast beans and d) dark roast beans. It was done using scavenging activity of DPPH radical by spectrophotometry and methods of reducing power.

Results:
The study showed that varietal differences (Robusta, Liberica, Arabica and Excelsa) and degree of roasting (green beans, light, medium, dark, and very dark) significantly affected (*P<0.05) the total phenolic content of coffee extracts. The strongest ability to scavenge DPPH radical was detected in green coffee beans. Among the roasted beans, the highest efficacy was displayed by the light roast sample, presumably due to it having the highest residual polyphenols content. Subsequent roasting caused a lesser decline in DPPH scavenging capacity, coinciding with the higher total phenolic content. Robusta variety had the lowest EC50 value of 1.28 mg/mL, which was significantly lower than the three other coffee varieties. Significant differences (*P<0.05) existed among four coffee varieties. Robusta had the highest reducing power among the four Philippine coffee varieties while Arabica had the lowest.

Conclusions & Perspectives:
This study examines the impact of different roasting conditions on the quality parameters of Philippine coffee extracts. The findings offer valuable insights that can be utilized to establish analytical markers for monitoring coffee extract quality and to optimize industrial processing methods for the production of superior coffee blends. Further in-depth investigations are necessary to elucidate the underlying chemical processes driving these changes and to validate the identified parameters for quality control in the coffee industry.

References:

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S9-O-04

Evaluation of taste and aroma of coffee and its relation to electroencephalography using emotion analyzer

Hanzawa Taku[1] (Taku-hanzawa@ucc.co.jp), Kakiuchi Misako[1], Hirabayashi Yuta[2], Shinozuka Manaka[2], Fukunaga Taiji[1], Takahata Makoto[1]

[1] *R&D Department, UCC Ueshima Coffee Co., Ltd.,, Kobe, Hyogo, Japan* ; [2] *Dentsu Science Jam Inc., Minato-ku, Tokyo, Japan*

Introduction:
Coffee consumption has become increasingly prevalent in various situations, serving diverse purposes. With the diversification of workstyles and the increase in telecommuting, people tend to look for coffee to play a psychological role, such as refreshing and relaxing. In the market, coffee products are chosen according to scenes and moods. There has been growing interest in exploring influence of coffee's taste and fragrance to customer's sensitivity. In this study, we compared taste data obtained using a sensory evaluation and electroencephalography (EEG) data obtained using an emotion analyzer for two types of coffee (light-roasted and deep-roasted) to determine the influence of coffee taste and aroma on sensory perception.

Methods:
Qualitative Data Analysis (QDA) revealed the differences in taste and aroma between two types of coffee (light-roasted and deep-roasted) across six specific items by eighteen in-house panel members trained in coffee evaluation. Twelve members of the same in-house panel filled out Temporal Dominance of Sensation (TDS) repeated twice. Simultaneously, an emotion analyzer measured EEG data to quantify five types of emotion values (concentration, stress, relaxation, arousal, and valence).

Results & Discussion:
We confirmed the difference in taste between the two types of coffee based on QDA and TDS evaluation data. The QDA method detected significant differences in six taste items and five aroma items ($p<0.05$), whereas the TDS method characterized coffee consumption in terms of aroma (top to swallow) and taste (middle to finish). In addition, significant differences were found in terms of "Concentration," "Relaxation," and "Arousal" ($p<0.05$) between the two coffee types. These results suggested a relationship between coffee taste and sensory perception.

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ORAL PRESENTATIONS

SESSION M1:
Miscellaneous 1

M1-O-01

The expansion of Geographical Indications on coffees: opportunities and challenges

Delphine Marie-Vivien (delphine.marie-vivien@cirad.fr), Isabelle Vagneron, Stéphane Fournier, Philippe Pédélahore, Estelle Bienabe, Fabrice Pinard, Maria Bouhaddane, Mikaël Linder, Claire Bernard-Mongin

CIRAD, UMR Innovation, Montpellier, France

Rationale:
Almost 30 years after the broad internationalization of the concept of geographical indications (GIs) that designate products having a given quality, characteristics or reputation from their place of origin (WTO Agreement on Intellectual Property Rights in 1995), it is striking that GIs have moved from concerning mostly wines and cheeses to coffees. Indeed, as for August 2023, more than 130 GIs on coffee have been registered worldwide, as listed by OriGIn [1]. Even if the use in practice of GIs for coffee and their benefits are contrasted and still need to be much better documented, GIs are recognized for their role in contributing to the decommodication of coffee, next to Fair Trade and other environmental labels.

Methods:
From the above list of GIs on coffee, a desk analysis of the specifications is being conducted to draw a typology in terms of: a) which kind of coffee products (steps localized in the geographical area), which size of the geographical area and which countries and b) which governance and right holders involved. This data is combined with a multidisciplinary literature review on GIs on coffee and field data from particular GIs on coffee surveyed by the authors.

Results:
1. GIs are mainly for intermediate products (green beans), with a critical step towards the final product (notably in terms of quality implications) occurring outside the geographical area of coffee growing. This reflects the global value chains with not all stakeholders localized in the same area, and the high power asymmetry between upstream players localized in the production countries and downstream ones, contrary to wine or cheese which have largely influenced GI institutional development.
2. Coffee value chains, at the level of the producing countries are still State driven, which, in combination with GIs considered as a public policy tool in many countries, conducts to GIs on coffee often decided and managed by State authorities.

Conclusions & Perspectives:
For GIs to play a more significant role in decommodifying coffee and improving producing countries capacity to benefit from these, it is critical to better address the following questions:
1. What sense does a GI make for an intermediate product where part of the quality is built elsewhere and where the added value is captured outside the geographical area of origin?
2. How to better address the role of private stakeholders in GI establishment and management?

References:
1. https://www.origin-gi.com/, last consulted [28 August 2023].

M1-O-02

Smallholder-ready mobile pictures for coffee crop yield prediction

Rivera Palacio Juan Camilo[1, 2, 3] (juancamilo.rivera@zalf.de), Bunn Christian[3], Ryo Masahiro[1, 2]

[1] *Environment and Natural Sciences, Brandenburgische Technische Universität (BTU) Cottbus–Senftenberg, Cottbus, Germany* ; [2] *Data Analysis & Simulation, Leibniz-Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany* ; [3] *Climate Action, International Center for Tropical Agriculture (CIAT), Rome, Italy*

Rationale:
The use of earth observation data, unmanned aerial vehicle imagery, and manual counting for coffee crop monitoring is a popular method for predicting crop yield in Latin America. However, the production conditions of the coffee crop, such as systems under shade, along with the time-consuming nature of the process, create barriers to the extensive use of these methods at plot and larger scales. This study aims to explore the use of machine vision of coffee trees for yield prediction at the tree level in agroforestry systems for Arabica species in Colombia and Peru, through the implementation of citizen science.

Methods:
This study employed an object detection deep learning model, 'You Only Look Once' (YOLO) v5, and manual counting, together with extensive field monitoring data comprising information from 977 farmers, 2954 trees, and 10195 mobile pictures. The model was trained with two varieties of trees: Catimor Cogollo Morado and Catimor Cogollo Verde, in Peru. The training dataset consisted of approximately 35,000 labeled cherries. After model training, we deployed the model in Colombia with the varieties 'variedad Colombia' and 'supremo' to test its usefulness in other regions.

Results:
The findings of this study indicate that yield prediction using mobile pictures reached an R-squared value of 70%. The model achieves good performance with unseen data, and its performance was as good as previous studies that employed more advanced but expensive techniques. Our study demonstrated that the method can generate yield predictions in seconds without the need for any expensive monitoring devices.

Conclusions & Perspectives:
The findings of this study highlight the potential of using mobile pictures as a means to generate yield data in areas where such data is lacking. The ability to obtain yield predictions at both plot and larger scales through mobile pictures opens up opportunities for efficient planning and improved access to financial services in agriculture. Future work should focus on the role of human users in the use of the machine vision system to further improve the accuracy of the results.

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M1-O-03

Microbial profiles of brazilian *Coffea arabica* and *Coffea canephora*

Louzada Pereira Lucas[1] (lucaslozada@hotmail.com), Gomes Reis Veloso Tomás[2], Soares da Silva Marliane de Cássia[2], Megumi Kasuya Maria Catarina[2], Moreli Aldemar Polonini[1]

[1] *Coffee Design, Instituto Federal do Espírito Santo, Venda Nova do Imigrante, ES, Brazil* ; [2] *BioAgro, Universidade Federal de Viçosa, Viçosa, MG, Brazil*

Rationale:
Coffea canephora and *Coffea arabica* are the two main species of coffee produced in Brazil and their associated microbiome plays a crucial role in their development. The diversity of the microbiota directly affects the organoleptic characteristics of the beverage, imparting unique aromas, flavors, and sensory complexity.
Methods:
We collected 180 samples of soil and fruits from these two species of Coffea on a national scale and sequenced the microbial DNA using the Illumina NovaSeq 600 platform.
Results:
We found that soil and fruits of C. arabica and C. canephora associate to different fungi and bacteria. Their fungal communities are more different among them in both soil (p-value = 16.84) and fruits (p-value = 8.64) than the bacterial communities (p-values of 5.14 and 1.16 for soil and fruit, respectively).
Conclusions & Perspectives:
C. arabica and *C. canephora* present different bacteria and fungi associated with their fruits and rhizospheric soils. The fungi and bacteria found in fruits can be potentially used to improve coffee beverage quality by use of these native yeasts in the fermentation process of fruits.

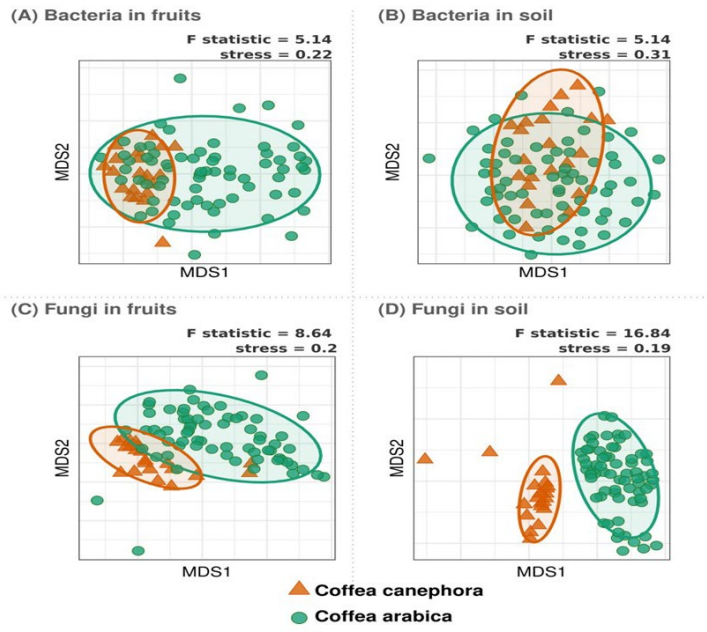

Figure 1: Beta diversity of microbial communities in soil and fruit of Coffea arabica and Coffea canephora. The greater the Permanova's F value, the more different are the microbial community associated to each species of Coffea.

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M1-O-04

Economic Analysis of the Technical Efficiency and Profitability of Coffee Production in Kogi state, Nigeria

Orisasona Taiye (taiwosona1976@gmail.com), Oluyole Kayode, Akinpelu Ayodele, Oladokun Yetunde

Economics and Extension, Cocoa Research Institute of Nigeria, Ibadan, Nigeria

This study examined the technical efficiency and profitability of coffee production in Kogi state, Nigeria. There have been a lot of research work on efficiency of annual crops with little attention given to perennial crops such as coffee.Therefore, the objectives of the study is to estimate the technical efficiency of coffee farming in the study area, determine the profitability of coffee production and to identify the constraints faced by coffee farmers. Multi stage sampling procedure was used to select the respondent for the study. The first stage involved the purposive selection of three Local Government Areas (LGAs) from the state. Second stage was the random selection of 15 coffee producing communities from the three selected LGAs (the selection was proportionate to size), while the third stage was the random selection of 400 coffee farming households from the selected communities. Data were collected with the use of well structured questionnaire. The Descriptive statistics, Gross Margin and Stochastic Production Function Frontier model (SPFF) were used to analyze the data. Results revealed that (24.8 %) of the farmers in the study area are between 60 and 70 years. Majority (77.8%) were males while 22.2% were females and 85% were married. About 30.5% of the respondents had between 21 and 30 years of the farming experience in coffee production. The result showed that production of coffee as a venture is profitable because for every ₦1 invested in the business, it yielded ₦1.39. The results of technical efficiency were obtained using stochastic production function frontier (SPFF) model. Econometric results obtained from frontier model indicate that labour, volume of chemical used and seed quantity has significant level of significance and positive sign. The constraints identified in the study were fire incidence, inadequate marketing channel, credit inaccesiblity, storage facilities, labour shortage and climate change. Thus the results suggest that there need to be policies geared towards enhancing production efficiency of farmers. Also, government and other lending agencies should also do more in assisting the respondent with loans in order to reduce the problem of inadequate capital among the farmers.

Keywords: Efficiency - Farming - Profitability - Production.

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ABSTRACTS TUESDAY 12 SEPTEMBER

KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 2:
Plant Pathology & Protection

S2-KN

Keynote lecturer

Overcoming pests,diseases and climate variability: the tale of Colombian coffee

Gaitán Alvaro (director.cenicafe@cafedecolombia.com)

Cenicafé, Federación Nacional de Cafeteros, Manizales, Caldas, Colombia

Rationale:
Colombian coffee farmers have persistently confronted challenges associated with pests, diseases, and extreme climate fluctuations. However, the combination of low profitability margins, emerging environmental and health regulations, and consumers' growing preference for sustainable agriculture has introduced additional constraints for maintaining a pivotal role as a significant provider of high-quality mild washed coffees.
Methods:
The implementation of comprehensive integrated management systems, incorporating legal, cultural, biological, genetic, and chemical control strategies, alongside crucial agronomical practices disseminated to coffee farmers through a nationwide extension service, has yielded substantial improvements in plantation conditions.
Results:
These improvements manifest in heightened productivity and remarkable resilience to extreme climatic conditions. Furthermore, the adoption of coffee farming technologies has had far-reaching effects on biodiversity preservation, water and soil resource conservation, and the economic margins of coffee producers.
Conclusions & Perspectives:
To sustain an advantage against the threats posed by diseases, pests, and climate variations while ensuring a steady coffee supply for the global market, it is imperative to further develop applications on genomics and biotechnology, mathematical modeling, robotics, remote sensing devices, portable agronomical equipment, and next-generation agrochemicals. These cutting-edge advancements will play a critical role in safeguarding the coffee industry and mitigating potential risks to disease outbreaks, pest infestations, and climate fluctuations in the future.

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S2-O-01

A chromosome-level genome resource for studying virulence mechanisms and evolution of the coffee rust pathogen *Hemileia vastatrix*

Tobias Peri[1] (peri.tobias@sydney.edu.au), Edwards Richard[2], Surana Priyanka[1], Mangelson Hayley[3], Inácio Vera[4], do Céu Silva Maria[4,5], Guerra-Guimarães Leonor[4,5], Park obert[65], Várzea Vitor[4,5], Batista Dora[4,5]

[1] *The University of Sydney, Camperdown, NSW, Australia* ; [2] *University of Western Australia, Perth, WA, Australia* ; [3] *Phase Genomics, Seattle, USA* ; [4] CIFC - *Centro de Investigação das Ferrugens do Cafeeiro (CIFC), Instituto Superior de Agronoia (ISA),/ Universidade de Lisboa, Oeiras, Portugal;* [5]*LEAF-Linking Landscape, Environment, Agriculture and Food Research Center, Associate Laboratory TERRA, ISA, Universidade de Lisboa, Lisboa, Prtugal*; [65] *Plant Breeding Institute, The University of Sydney, Narellan, Australia*

Recurrent epidemics of coffee leaf rust, caused by the fungal pathogen *Hemileia vastatrix,* have constrained the sustainable production of Arabica coffee for over 150 years. The ability of *H. vastatrix* to overcome resistance in coffee cultivars and evolve new races is inexplicable for a pathogen that supposedly only utilizes clonal reproduction. Understanding the evolutionary complexity between *H. vastatrix* and its only known host, including determining how the pathogen evolves virulence so rapidly is crucial for disease management. Achieving such goals relies on the availability of a comprehensive and high-quality genome reference assembly. To date, two reference genomes have been assembled and published for *H. vastatrix* that, while useful, remain fragmented and do not represent chromosomal scaffolds. Here, we present a complete scaffolded pseudochromosome-level genome resource for *H. vastatrix* strain 178a (Hv178a). Our initial assembly revealed an unusually high degree of gene duplication (over 50% BUSCO basidiomycota_odb10 genes). Upon inspection, this was predominantly due to a single scaffold that itself showed 91.9% BUSCO Completeness. Taxonomic analysis of predicted BUSCO genes placed this scaffold in Exobasidiomycetes and suggests it is a distinct genome, which we have named Hv178a associated fungal genome (Hv178a AFG). The high depth of coverage and close association with Hv178a raises the prospect of symbiosis, although we cannot completely rule out contamination at this time. Our research is ongoing to address phasing of the haploid genomes and further charactarising the unusual Hv178a AFG. The highly contiguous Hv178a genome (546 Mbp) is localised to 11 pseudochromosomes (51.5 Mb N50), and provides the foundation for advanced studies into the evolution, pathology and genome structure of this important pathogen of coffee.

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S2-O-02

BRE4: Advancing Sustainable Coffee Plantations with a Cost-Effective Bionematicide

Asyiah Iis Nur[1] (iisnaza.fkip@unej.ac.id), Pradana Ankardiansyah Pandu[2]

[1] *Biology Education, Universitas Jember, Jember, East Java, Indonesia* ; [2] *Plant Protection, Universitas Jember, Jember, East Java, Indonesia*

The recent surge in plant parasitic nematode infections, coupled with the escalating surface temperatures caused by climate change, has become a pressing concern. Synthetic nematicides used in coffee plantations are costly and unsustainable. Therefore, the development of a cost-effective bionematicide (BRE4) has been pursued, utilizing active ingredients derived from endophytic bacteria and rhizobacteria (1,2). This study aims to evaluate the efficacy of BRE4 in controlling nematode infections and supporting sustainable coffee plantation practices. The study involved conducting extensive experiments to assess the performance and potential of BRE4. The control of *Meloidogyne* spp and *Pratylenchus* sp nematodes in both Arabica and Robusta coffee plants was examined, both in controlled greenhouse environments and open fields. The BRE4 significantly enhances coffee plant performance, increasing crop yields and inducing resistance mechanisms. These findings contribute to the development of sustainable practices in the coffee industry.The utilization of BRE4 holds promise in supporting sustainable coffee plantation practices and mitigating the challenges posed by plant parasitic nematodes.

References:

1. Asyiah et al. 2022. Pakistan Journal of Phytopathology. DOI: 10.33866/phytopathol.034.02.0789.
2. Asyiah et al. 2021. Biodiversitas Journal of Biological Diversity. DOI: 10.13057/biodiv/d220630.

S2-O-03

Climate change and its impact on economically important coffee diseases in India

M. Sudha[1] (sudhaccri@gmail.com), Machenahalli Santoshreddy[1], S. Madhu Giri[2], A. P. Ranjini[2], J. S. Nagaraja[3], M. Senthil Kumar[3]

[1] *Central Coffee Research Institute, Plant Pathology Division, Coffee Board of India, Chikkamagaluru, Karnataka, India* ;
[2] *Central Coffee Research Institute, Plant Pathology Division, Coffee Board of India, Chikkamagaluru, Karnataka, India* ;
[3] *Central Coffee Research Institute, Coffee Board of India, Chikkamagaluru, Karnataka, India*

Rationale:
Coffee being a perennial crop, harbours pathogens on all parts of the plant at any time and the intensity of disease increases under favourable conditions. In recent years, coffee growing regions in South India received unusual rains with erratic distribution patterns due to climate change. Unprecedented rains throughout the year resulted in wetness in coffee plantations, which in turn triggered and activated the fungal pathogens. Abiotic factors influence all stages of host and pathogen life cycles as well as development of diseases 2017). Cloudy and intermittent rains received during the recent years favoured the spread and development of coffee leaf rust disease. Under this changing climatic situations, leaf rust incidence and severity were recorded to understand the bhaviour of leaf rust pathogen*Hemilieia vastatrix* and observations on the incidence and intensity of rot diseases were also recorded.

Methods:
The development of coffee diseases like leaf rust, black rot, stalk rot, leaf and berry rot and the damage caused by these pathogens are monitored at regular intervals continuously from last five seasons in coffee growing regions of Karnataka state, India. Weather parameters like maximum and minimum temperature, relative humidity, rainfall and sunshine hours etc. were recorded and correlated with the disease incidences. *In vitro* and field experiments were conducted to manage these emerging pathogens.

Results:
With the change in climatic conditions, the bhaviour of the pathogens and the diseases inflicting to coffee are also differing in the recent times. These climatic conditions during monsoon season provided ideal conditions for flare up of diseases such as black rot, stalk rot, leaf spot and berry diseases causing defoliation and premature fruit drop affecting crop production to a great extent. Though its occurrence and prevalence are only for a period of 3-4 months during the rainy season, its impact on crop loss is substantial. Further, variation in seasonal distribution of rainfall in the recent years resulted in deviation in the leaf rust disease progression pattern and spray schedule is altered.

Conclusions & Perspectives:
It can be concluded that there is significant relationship between changes in the climatic conditions as we have witnessed the emergence of minor diseases appearing as major problem, yield loss, deterioration in quality of coffee seeds and affecting future cropping wood. Timely adoption of integrated management strategies including the new fungicide molecules and cultural operations helps to tackle these problems effectively.

References:

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S2-O-04

Can commercial bioinoculants available on the market in Vietnam protect coffee seedlings from *Meloidogyne incognita* infestation under controlled conditions?

Nguyen Van Long[1, 2, 3] (s222117312@deakin.edu.au), Herrmann Laetitia[1, 3], Le Dinh Thao[4], Nguyen Van Chung[4], Nguyen Van Liem[4], Enez Aydin[1, 5], Brau Lambert[1, 5], Venugopal Abhirami[1, 5], Lesueur Didier[1, 3, 6]

[1] *School of Life and Environmental Sciences, Deakin University, Melbourne, Victoria, Australia* ; [2] *Pepper Research and Development Center, Pleiku, Gia Lai, Vietnam* ; [3] *Common Microbial Biotechnology Platform (CMBP), International Center for Tropical Agriculture (CIAT), Ha Noi, Vietnam* ; [4] *Plant Protection Research Institute (PPRI), Ha Noi, Vietnam* ; [5] *Centre for Regional and Rural Futures (CeRRF), Deakin University, Melbourne, Victoria, Australia* ; [6] *CIRAD, Ha Noi, Vietnam*

Rationale:
Vietnam is the world's largest Robusta coffee exporter and contributes to around 53% of the global Robusta's coffee market, with 695,000 ha of land dedicated to coffee production. However, the coffee industry in Vietnam is facing major challenges due to several decades of intensive management and mis-management. Soil biodiversity is significantly reduced and soil physio-chemical properties highly degraded, resulting in increased Soil Borne Pests and Diseases (SBPD), including Fusarium and phytopathogenic nematodes (*Pratylenchus* and *Meloidogyne*). These phytopathogenic nematodes are widely distributed in the soil, damaging the coffee seedlings and responsible for 40% of the new plantations being removed soon after planting.

Methods:
The utilization of commercial bioinoculants containing microbial biocontrol microorganisms currently available on the market in Vietnam has been investigated under greenhouse conditions to assess their capacity to control the infection of *Meloidogyne incognita* isolated from roots of highly infected coffee trees in the Central Highlands. A list of 15 commercial bioinoculants, a positive control (chemical nematicide) and a negative control (untreated) were tested using two protocols: (1) nematodes inoculated to coffee seedlings 15 days after the application of the bioinoculants and (2) nematodes inoculated to coffee seedlings 15 days before the application of the bioinoculants.

Results:
Our results showed that regardless of treatments and the protocol, the presence of *M. incognita* did not induce any plant mortality. Chlorophyll content index, above fresh biomass, and nematode populations in the soil and roots were significantly different with bioinoculants compared to the negative control. The pre-application of bioproducts resulted in better nematode control than application performed post infection with *M. incognita*. The four most effective bioinoculants tested, suppressed 63%-81% of *M. incognita* population compared to the negative control regardless of the protocol. With the chemical nematicide control, the inhibition of *M. incognita* was 88-93%.

Conclusions & Perspectives:
Our study identified effective commercial bioinoculants that farmers can apply at the nursery to protect coffee seedlings. These bioinoculants will now be tested in the field, in coffee plantations with soil infested by *M. incognita,* to determine if they can effectively contribute to significantly reduce the populations of these SBPDs, in combination with/without other management practices such as lime or biochar applications.

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KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 5:
Climate change - Sustainability - Labels

S5-KN

Keynote lecturer

Integrating climate risk management and insurance for sustainable coffee production in a changing climate

Kath Jarrod (jarrod.kath@usq.edu.au)

School of Agriculture and Environmental Science, University of Southern Queensland, Toowoomba, QLD, Australia

The risks that climate variability and change pose to coffee production are complex and multi-faceted. Meeting these challenges is essential for ensuring that coffee production is sustainable and profitable into the future. To successfully meet these challenges an integrated approach with three key steps is needed: (1) Accurate identification and quantification of climate risk, (2) the development of sustainable management approaches linked to these risks and (3) in cases where risks are too extreme or costly to be managed the strategic use insurance options to transfer risk. In this talk research across these three key elements of integrated sustainable coffee management will be outlined with examples from Asia (Indonesia, Vietnam, and India) and around the world given for the world's key production species Arabica and robusta. The importance of a data driven and comprehensive climate risk assessments that consider climatic risks beyond just rainfall and temperature change will be emphasized. Management approaches, such as the efficient use of irrigation and the importance of early-warning forecasting approaches will also be outlined. Finally, the development and piloting of a world-first coffee climate insurance program for Vietnamese coffee farmers will be highlighted.

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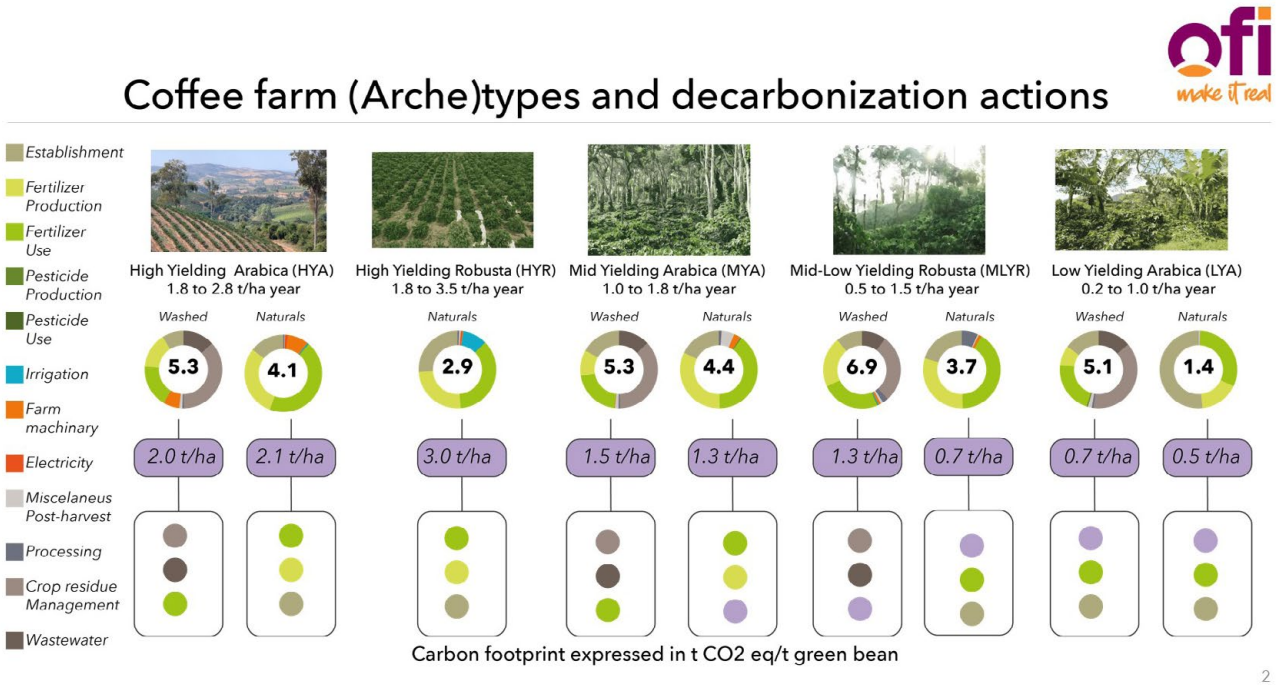
S5-O-01

Coffee system archetypes to prioritize decarbonization and regenerative agriculture practices

van Asten Piet[1] (piet.vanasten@ofi.com), Sarmiento-Soler Alejandra[2], Makona Brenda[3], Mushi Paolo[4], Dufour Jeremy[5], Stewart Christopher[6]

[1] *ofi (Olam Food Ingredients), Singapore, Please select, Singapore* ; [2] *ofi (Olam Food Ingredients), Goettingen, Germany* ; [3] *ofi (Olam Food Ingredients), Amsterdam, Netherlands* ; [4] *ofi (Olam Food Ingredients), Bogota, Colombia* ; [5] *ofi (Olam Food Ingredients), Geneva, Switzerland* ; [6] *ofi (Olam Food Ingredients), London, United Kingdom*

Coffee contributes to climate change. To understand factors contributing to the coffee carbon footprint and design a decarbonization pathway, ofi used AtSource © to develop nine Coffee System Archetypes based on species (i.e. Arbacia/Robusta), yield level (High/Moderate/Low), and post-harvest processing (Pulped/Natural). Nitrogen fertilizers dominate the GHG emissions of high-yielding naturals, wet waste emissions (CH4, N2O) drive footprints of pulped coffees, and low yield and land clearing cause high footprints in low-input systems. Carbon commitments have been embedded in a Regenerative Agriculture narrative, aiming to restore biodiversity, soil health and water resources. Implementation seems complex due to a large and diverse set of recommended practices. We observe that in every archetype the biggest positive change is achieved by eliminating/reducing 1-2 degenerative practices while encouraging 2-3 regenerative practices. In this presentation we will explain the logic of the nine archetypes, the breakdown of their footprint, and the 2-3 key entry points per archetype to reduce footprints without requiring large investments, big risks, or profitability loss for farmers.



Example of carbon footprint archetypes of coffee production systems (source: 2021 AtSource data) and priority action points for decarbonization.

S5-O-02

Using farmer knowledge to promote suitable shade tree species with ShadeTreeAdvice

Rigal Clément[1, 2] (clement.rigal@cirad.fr), Wagner Sigrun[3], Nguyen Mai Phuong[2], Jassogne Laurence[4], Vaast Philippe[5]

[1] *UMR Absys, CIRAD, Montpellier, France* ; [2] *Vietnam office, ICRAF, Hanoi, Vietnam* ; [3] *Manchester Metropolitan University, Ecology and Environment Research Centre, Manchester, United Kingdom* ; [4] *TerraQ Pte. Ltd., Singapore, Singapore* ; [5] *UMR Eco&Sols, CIRAD, Montpellier, France*

The promotion of coffee agroforestry systems requires the identification of locally suitable shade tree species tailored to farmers' needs and constraints. ShadeTreeAdvice was developed to facilitate this identification process. This method relies on farmers' knowledge for data collection. The results are subsequently uploaded to an online decision-support tool (www.shadetreeadvice.org). Since 2016, ShadeTreeAdvice was implemented in 9 coffee-growing areas worldwide. We review these studies to derive general insights in order to improve the methodology and strengthen future studies.
The ShadeTreeAdvice database documents 180 tree species and their provision of ecosystem services, offering substantial amount of information to guide the selection of suitable shade tree species in the studied areas. The review shows the importance of trade-offs between economic and environmental issues. It also highlights the need of better considering farming practices and labor requirements, particularly in regions where intensive practices relying on inputs have partially replaced ecosystem services. We anticipate that the database will keep expanding with new studies in the years to come.

Map of ShadeTreeAdvice studies related to coffee.

References:

1. Rigal, C., Wagner, S., Nguyen, M. P., Jassogne, L., & Vaast, P. (2022). ShadeTreeAdvice methodology: Guiding tree-species selection using local knowledge. People and Nature. doi:https://doi.org/10.1002/pan3.10374

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S5-O-03

Detecting deforestation in Vietnam coffee growing regions

Browning David (sam@enveritas.org)

Enveritas Inc, Old Greenwich, Connecticut, USA

Rationale:
Many governments, corporations, and non-profit organizations have a strong motivation to protect rainforests and take action against deforestation, particularly if this deforestation occurs as a result of exportable commercial commodities such as coffee or cocoa. However, there have traditionally been significant limitations in measuring and detecting coffee region deforestation at scale. The main model utilized by major environmental organizations is generated by Global Forest Watch (GFW). This approach suffers from several constraints; inability to differentiate commercial plantations from old-growth forests in protected areas, use of low-resolution imagery that has difficulty detecting deforestation, and inability to penetrate cloud cover which can obscure 80% of optical satellite images.

Methods:
Recent developments in machine learning and satellite imagery can overcome these limitations. We have built a deep learning model to track small-scale deforestation and differentiate plantations from forest using the most recent advances in satellite imagery and machine learning. The model is ground-truthed by our wide network of field agents across coffee origins in order to assess the degree of accuracy of the computer model predictions.

Results:
Such a rigorous assessment of deforestation in the coffee sector has not been carried out before. We will present a robust, methodologically-consistent approach to answer the question “How accurate is the GFW data set for deforestation detection, as well as the results of the model, currently available for all coffee-producing regions of Vietnam, to determine if this approach is a more effective tool for the coffee industry. These Answers Will Underpin Future Research And Policy Work.

Conclusions & Perspectives:
We believe that this innovation has the potential to become an important new tool for the coffee sector in its efforts to combat deforestation and mitigate climate change. It can not only underpin future research but also has important policy implications for organizations on the ground. Indeed, in the context of an expanding regulatory environment led by a more demanding civil society, it provides an accurate, consistent, and transparent way for organizations to report on deforestation events in their supply chains and monitor them. At the same time, we hope that it will open a broader discussion regarding the potential for machine learning to apply new innovations to systemic problems that plague the coffee sector.

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S5-O-04

Innovative strategies to attract youth and women participation in the coffee value chain in Tanzania

Jeremiah Magesa Marco[1] (jeremagesa@gmail.com), Malinga Sophia[2], Shao Godbless[3], Ng'homa Nyabisi[4], Pangalas Dismas[5], Hamad Almasi[6], Kilambo Deusdedit[7]

[1] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania* ; [2] *TaCRI Mwayaya Sub-station, Tanzania Coffee Research Institute (TaCRI), Kigoma, Kigoma, Tanzania* ; [3] *TaCRI Ugano Sub-station, Tanzania Coffee Research Institute (TaCRI), Mbinga, Ruvuma, Tanzania* ; [4] *TaCRI Maruku Sub-station, Tanzania Coffee Research Institute (TaCRI), Bukoba, Kagera, Tanzania* ; [5] *TaCRI Mbimba Sub-station, Tanzania Coffee Research Institute (TaCRI), Mbozi, Songwe, Tanzania* ; [6] *TaCRI Sirari Sub-station, Tanzania Coffee Research Institute (TaCRI), Tarime, Mara, Tanzania* ; [7] *Appropriate Crop Improvement Research Programmes Continue to be Implemented, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania*

Rationale:
Coffee production in Tanzania is facing many challenges such as aged coffee trees, aged coffee growers, and low youth and women participation. Youth and Women contribute significantly to agriculture and food security around the world, and their empowerment is critical to ensure sustainable development of many sectors. They are amongst the ergogenic groups in any sector of development. Yet, youth and women have continued to face unequal access to training, resource ownership, and opportunity to adopt and practice new agricultural technologies, run their businesses, and use their cash income to improve their livelihoods. Therefore, this paper describes various strategies that TaCRI is using to attract the participation of youth and women in the coffee value chain in the coffee-growing zones in Tanzania.
Methods:
Coffee production in Tanzania is reported to be 60,000 tons on average for the past ten years fluctuating between 50,000 and 74,000 tons which is below the country's potential of producing 200,000 tons annually. In addressing the problem of low productivity and production, TaCRI is implementing various strategies that aim at attracting the participation of young adults and women in the coffee value chain. Such strategies include but are not limited to the formation of youth and women wings, capacity buildings to youth and women wings on coffee agronomy and primary processing, seedlings multiplication, conducting exchange visits, and establishment of youth and women-managed demonstration plots.
Results:
Notable achievements have been realized whereby the participation of youth and women has increased to 30% for Youth and 25% for women respectively. Furthermore, coffee productivity has improved in the world and women managed coffee demonstration plots and coffee farms.
Conclusions & Perspectives:
This paper has outlined various innovative strategies that TaCRI is using to attract the participation of Youth and Women in the coffee value chain to address the country's low coffee productivity and production. Therefore, multi-approach strategies in addressing the problem of low coffee productivity and production need to be promoted to attract more Youth and Women participation in the coffee value chain.

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2. Orodho, A.B. 2012. Dissemination and utilization of research technology on forage and agricultural by-products in Kenya. Htt://www.fao/wairdocs/ILRI/x5536E/x556E/x5536e05.htm. Accessed on 17.03.2023.

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ORAL PRESENTATIONS

SESSION 8:
Coffee Chemistry & Sensory sciences

S8-O-04

New insights into the complex world of coffee flavour chemistry

Fisk Ian[1, 2] (ian.fisk@nottingham.ac.uk)

[1] *1. International Flavour Research Centre, University of Nottingham, Loughborough, Leicestershire, United Kingdom* ; [2] *International Flavour Research Centre (Adelaide), The University of Adelaide, Adelaide, SA, Australia*

Coffee aroma chemistry consists of a complex mix of volatiles formed through a series of interconnecting thermal reactions. Whilst significant advances have been made in explaining these reactions and how they develop from simple precursors. There is less knowledge on how these reactions interconnect and how this complex mix of final reaction products (which drive sensory attributes) can be controlled at a single coffee bean level or small batch level.

We combined two unique collections of coffee 1) a bespoke series of green coffee roasted under controlled conditions to represent the wider coffee market and 2) a series of single coffee beans roasted individually to enable a true understanding of single coffee bean variability. Furthermore, a novel coffee bean sorting technique was trialled (hyperspectral imaging) for segregating beans based on flavour precursors.

Volatile compounds of single coffee beans were analysed using Solid Phase Micro Extraction-Gas Chromatography-Mass Spectrometry and Gas Chromatography-Olfactometry and further integrated for application using advanced data analytical techniques.

To demonstrate the applicability of the approach, single beans were sorted using a novel sorting technique, to form novel prototypes products. This is industrially relevant as it will provide new rapid tools for quality evaluation, opportunities to understand and minimise heterogeneity during production and roasting and ultimately provide the tools to define and achieve new coffee flavour profiles.

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S8-O-05

Smart on-line coffee roasting process control by MassSpectrometry: Real-Time prediction model for coffee-roasting degree, brew antioxidant capacity and sensory attributes

Zimmermann Ralf[1] (ralf.zimmermann@uni-rostock.de), Czech Hendryk[1], Heide Jan[1], Ehlert Sven[2], Koziorowski Thomas[3]

[1] *Chair of Analytical Chemistry, University of Rostock, Rostock, Germany* ; [2] *Photonion HmbH, Schwerin, Germany* ; [3] *Probat GmbH, Emmerich, Germany*

Rationale:
Industrial coffee roasting traditionally relies on bean color and sensory analysis to assess the quality of roasted coffee. However, sensory analysis is time-consuming and cannot provide real-time feedback on the roasting process. The use of on-line mass spectrometry is a promising monitoring tool for coffee roasting, providing real-time information on the chemical composition of the roasting gases. By this the roasting chemistry is comprehended, allowing for the development of digital models to on-line predict, e.g. the final brew taste and the brew antioxidant content.

Methods:
Photoionization time-of-flight mass spectrometry (PI-TOFMS) has shown great potential in coffee roasting process analysis. The technique is highly sensitive and selective and is able to detect a wide range of volatile and semi-volatile organic compounds in the roasting gases. This makes it well-suited for monitoring the chemical changes that occur during the coffee roasting process. In combination with sensory evaluation of differently roasted coffees (cupping), determination of roast degree and the antioxidant capacity, a model for on-line prediction of sensory attributes etc. from roasting process by on-line PI-TOFME data was built.

Results:
A successful prediction model based on PI-TOFMS data (resonance-enhanced multiphoton ionization, REMPI or single photon ionization, SPI) was developed. to develop a new modeling approach for predicting the final brew taste of roasted coffee. For this, the system was coupled to an industrial tangential roaster, and a total of 50 roasts were monitored and cupped by an expert panel and analyzed. A preliminary partial least square-model was computed using sensory data from the first half of the roasts, and the results showed that PI-TOF-MS has the potential to provide real-time information of sensory attributes, which can help in quality control and the development of new roast recipes.

Conclusions & Perspectives:
Overall, the study highlights the potential of PI-TOF-MS as a valuable process-monitoring tool for, e.g. sensory real-time prediction, providing a tool for optimized roasting process parameter development (pilot plant) and monitoring (production plant).

References:

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S8-O-06

The chemistry behind the coffee flavour evolution over time: an omicapproach

Liberto Erica[1] (erica.liberto@unito.it), Strocchi Giulia[1], Pellegrino Gloria[2], Bicchi Carlo[3]

[1] *Dipartimento di Scienza e Tecnologia del Farmaco, Università degli Studi di Torino, Torino, Italy* ; [2] *Luigi Lavazza S.p.A., Torino, Italy* ; [3] *Università degli Studi di Torino, Torino, Italy*

Rationale:
Coffee quality is a multidimensional attribute influenced by a series of genetic precursors, environmental factors and especially post-harvest processes such as roasting and storage conditions that affect sensory and chemical properties [1,2,3]. Storage is strongly influenced by various environmental conditions: moisture, temperature and oxygen are the basic dynamic forces that play a fundamental role in a number of deterioration processes, such as volatilisation of odour molecules (VOCs), the release of CO2, oxidative reactions with the formation of off-notes and the development of rancidity [2,4-6]. This work deals with the investigation of a flavoromics approach to study the chemistry behind the changes in coffee flavour during storage.

Methods:
The chemical data of the investigated coffee samples were obtained by analysing both volatile and non-volatile profiles (i.e. lipids and phenolic fractions including alkaloids) using HS-SPME-GC-MS and HPLC-UV/DAD. Different commercial coffee capsules in different packaging, namely standard (multilayer foil with aluminium barrier) (and eco-capsules, batches (3 batches each) and blends (P and B, 100% Arabica and I 50/50% Arabica/Robusta) were analysed. Samples were stored under stress conditions (65% RH and 45°C) and monitored over a period from T0 to T180 days for the standard caps and from T0 to T90 days for the eco caps. Acidity, peroxide value and p-anisidine were evaluated by spectrophotometric analysis. In parallel, the sensory tests were carried out by an expert panel.

Results:
A series of volatile compounds were detected in the oxidized samples, including 3 VOCs exhibiting pungent, rancid and acidic notes and appearing in sensory unacceptable samples independently from blends, batches and packaging. The phenolic fraction and alkaloids do not vary significantly ($p > 0.05$). The fraction is very stable over time regardless of packaging and mixture. The evolution of the free fatty acids (FFAs) was correlated with the peroxides, p-anisidine and acidity values, the pH and UR % measurements and the VOCs.

Conclusions & Perspectives:
The results show that the different blends behave differently over time in the standard packaging with respect to Eco-caps the latter presenting a shorter shelf-life.

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S8-O-07

Sensory and metabolic profiles of *Coffea canephora* accessions from DR Congo

Bollen Robrecht[1, 2] (robrecht.bollen@plantentuinmeise.be), Rojo-Poveda Olga[3], Verleysen Lauren[2, 4], Ntumba Benjamin Katshela[5], Ndezu Rachel Angirio[5], Mavar Hélène[5], Tshimi Aaron Ebele[6], Vandelook Filip[1], Ruttink Tom[4], Souard Florence[3], Honnay Olivier[2], Stévigny Caroline[3], Delporte Cedric[3], Stoffelen Piet[1]

[1] *Meise Botanic Garden, Meise, Belgium* ; [2] *University of Leuven, Leuven, Belgium* ; [3] *Université Libre de Bruxelles, Brussels, Belgium* ; [4] *Flanders Research Institute for Agriculture, Fisheries and Food, Melle, Belgium* ; [5] *Université de Kisangani, Kisangani, Congo - Kinshasa* ; [6] *Institut National des Etudes et Recherches Agronomique, Yangambi, Congo - Kinshasa*

Rationale:
The *ex-situ* Robusta coffee (*C. canephora*) collection of INERA Yangambi (DR Congo) contains a considerable yet underexplored diversity of genetic resources, including wild accessions and local varieties. We performed a detailed organoleptic evaluation of the accessions to explore the agronomic potential of the collection. This was supported by an untargeted metabolomics analysis of the plant material to discover chemical differences and metabolite markers of quality.

Methods:
The Fine Robusta cupping protocol (Coffee Quality Institute, 2019) was extended to allow for qualitative descriptive cupping in order to evaluate 80 genotypes and 20 post-harvest processing samples from the INERA collection. Green leaves, green beans, and roasted beans of several genotypes were analyzed for their chemical fingerprints through LC-HRMS, and the obtained data were analyzed with an untargeted metabolomics approach (Souard et al., 2018).

Results:
A large spread in cupping quality was discovered, with the highest-scoring samples having unique flavor profiles. The flavor profiles were not correlated with the genetic origin of the accessions, as we found unique profiles among the different origins. Post-harvest processing significantly impacted the quality score, and we found sensory descriptors correlated with processing.
Untargeted metabolomics revealed a separation of samples based on quality and metabolites found in the plant material that can be used as possible markers for coffee quality.

Conclusions & Perspectives:
A considerable commercial potential was found for the INERA Yangambi collection. The use of sensory descriptors allowed for the discovery of unique flavor profiles as well as the differentiation of post-harvest processing methods. Untargeted metabolomics of coffee beans and leaves resulted in the significant separation of coffee quality and found possible markers of quality that could assist in the selection of high-quality Robusta coffee.

References:

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S8-O-08

Home-brewed coffee – The influence of temperature, flow and grind size on aroma composition of espresso coffee

Cleve Nina[1, 2] (nina.cleve@ivv.fraunhofer.de), Stenzel Andreas[1], Engels Michelle[1], Beauchamp Jonathan[1]

[1] *Department of Sensory Analytics and Technologies, Fraunhofer Institute for Process Engineering and Packaging IVV, Freising, Germany* ; [2] *Department of Chemistry and Pharmacy, Chair of Aroma and Smell Research, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany*

Rationale:
Home coffee brewing is a growing trend, accompanied by a steady rise in coffee machine sales. Manifold online blogs and vlogs claim to provide the ultimate tricks on how to prepare the perfect espresso coffee, but scientific studies on how and to which extent extraction parameters influence the extraction of aroma and non-volatile compounds are inconsistent, thus the jury is still out on how to create the perfect final beverage. In the present work, the influence of the main extraction parameters of espresso coffee on aroma compounds in the final beverage were investigated, specifically the particle size of coffee grinds, as well as the water temperature and flow rate of extraction.

Methods:
Coffees were prepared using different extraction settings, with each preparation sampled in ten fractions in order to investigate the extraction kinetics of constituent aroma compounds. Qualitative and quantitative changes in the aroma compound composition of these fractions were analysed using a novel approach consisting of a liquid calibration unit (LCU) coupled with proton transfer reaction time-of-flight mass spectrometry (PTR-TOFMS). The LCU system was used to vaporize the individual filtered coffee samples, allowing constituent volatiles to be analysed and quantified directly in the gas phase by PTR-TOFMS. Additional sensory evaluations of the final beverages by both consumer and trained panels allowed changes in aroma compound compositions to be correlated with perceptual differences.

Results:
Contrary to expectations, the variation of temperature (80, 89, 98 °C), flow rate (1, 2, 3 mL/s) and particle size (mean sauter diameters: 69.3, 76.6, 76.9 µm) had little impact on the extraction kinetics or extracted amounts of aroma compounds. The highest extraction temperature and lowest flow rate led to greatest extraction, especially for non-polar compounds. Sensory evaluations indicated a shift in sensory perception for high temperature extracts.

Conclusions & Perspectives:
Changes in extraction parameters influenced the aroma composition of espresso coffee beverage only marginally, although only one type of coffee was investigated, thus the degree to which these results are translatable to other types of coffee remains unknown. Due to the observed limited extent of influence of these extraction parameters on the coffee beverage aroma, a greater driver for coffee aroma is expected to be the coffee bean type and roasting degree.

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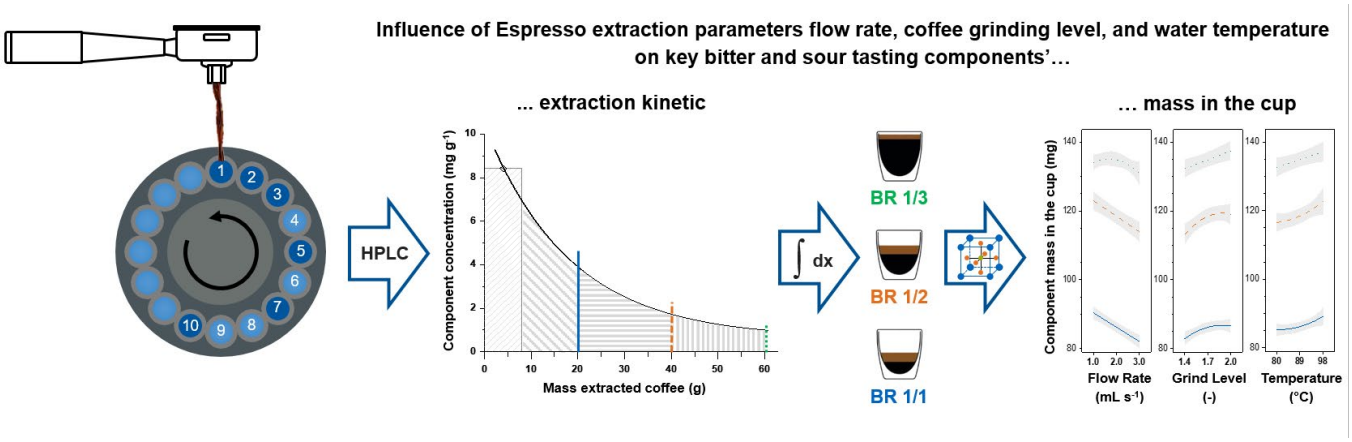
S8-O-09

Influencing Espresso bitterness and sourness based on extraction kinetics

Schmieder Benedikt[1] (benedikt.schmieder@tum.de), Pannusch Verena[2], Vannieuwenhuyse Lara[1], Müller Michaela[1], Briesen Heiko[2], Minceva Mirjana[1]

[1] *Biothermodynamics, Technical University Munich, Freising, Germany* ; [2] *Chair of Process Systems Engineering, Technical University Munich, Freising, Germany*

Rationale:
Brewing espresso coffee is considered a craft, by some even an art, as the underlying physical processes are not yet completely understood. Therefore, this work analyzed the influence of flow rate, coffee grinding level, and water temperature on key bitter and sour tasting components' extraction kinetics.
Methods:
The component extraction kinetics were determined by collecting the extracted espresso coffee in ten consecutive fractions and analyzed for key bitter and sour tasting components by HPLC. The parameter influence on the components' mass in the cup for the brew ratios 1/1, 1/2, and 1/3 are derived from the extraction kinetics by integration.
Results:
The parameter influences of flow rate, coffee grinding level, and water temperature on key bitter and sour-tasting component masses in the coffee cup can easily be masked by inconsistent extracted espresso coffee mass.
Conclusions & Perspectives:
For practical applications to extract a consistent expresso coffee, the first parameter to optimize is the brew ratio with a controlled amount of extracted coffee mass in the cup.



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S8-O-10

Model-Based Prediction of Espresso Taste – Brewing Control Chart for Varying Flow Rate, Temperature, and Coffee to Water Ratio

Pannusch Verena Bernadette[1] (Heiko.Briesen@tum.de), Schmieder Benedikt Karl Leonhard[2], Vannieuwenhuyse Lara[2], Minceva Mirjana[2], Briesen Heiko[1]

[1] *Process Systems Engineering, TU Munich, Freising, Germany* ; [2] *Biothermodynamics, TU Munich, Freising, Germany*

Rationale:
Various mathematical models for espresso extraction have been presented in the past to capture the dynamics and influencing factors of coffee taste during espresso brewing. A model describing the influence of process variables on the extraction kinetics of taste-relevant compounds for quantifying and predicting changes of taste has, however, still been lacking. We present an experimentally validated model that incorporates the influences of water temperature and flow rate on the extraction kinetics of three individual solutes and total solutes.

Methods:
Our model is based on the model by Moroney et al. (2019)[1] and extends it by relating its parameters to temperature and flow rate. The model parameters were estimated using experimental concentration data of caffeine, trigonelline, chlorogenic acid, and total solutes at different temperatures and flow rates. The model predictions were validated using experimental data at dynamic temperature and flow rate profiles. An espresso brewing control chart was developed relating the yield of all analytes to temperature and flow rate at various beverage volumes.

Results:
Our study reveals that a decrease in flow rate (longer extraction time) and an increase in temperature lead to a small increase in the concentrations of all analytes. In contrast to a previous study by Salamanca et al.[2], temperature gradients did not result in significantly different concentrations. Our model described the extraction kinetics and quantitative changes of concentrations with temperature and flow rate at high accuracy. The results moreover showed that the model relates the molecules' polarity to extraction kinetics. Our espresso brewing control chart (software tool) visualized that the polar molecule trigonelline was extracted faster than the less polar compounds caffeine and chlorogenic acid.

Conclusions & Perspectives:
Our mechanistic model is suitable to predict the extraction kinetics of different compounds at varying water temperature and flow rate. The espresso brewing control chart may be used in the future to optimize coffee to water ratio and flow rate to obtain optimal taste.

References:

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KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 1:
Coffee plant science

S1-KN

Keynote lecturer

Root microbiota and induced systemic resistance

Pieterse Corné (c.m.j.pieterse@uu.nl), Song Yang

Plant-Microbe Interactions, Utrecht University, Utrecht, Netherlands

Plant microbiome research has emerged as a new imperative in agriculture. The realization that thousands of microbial species are an integral part of the biology of plants and expand their genomic potential comes with great new opportunities for microbiome-assisted agriculture. Discoveries that root microbiota support plant growth, development, nutrition and immunity fostered bio-based crop system approaches to reduce the use of agrochemicals. However, the dream of microbiome-assisted agriculture as a genuine sustainable contribution to global agriculture will require a deep understanding of the genetic, ecological and evolutionary principles underlying plant-microbiome interactions. Research in the Plant-Microbe Interactions group at Utrecht University is focused on understanding plant-beneficial functions encoded by the root microbiome and the role of plant genes facilitating these functions. Recently, we demonstrated that upon foliar pathogen infection, plant roots recruit a consortium of synergistic microbes to their rhizosphere that in turn trigger an immune response in the whole plant body. We also discovered that specific metabolites in root exudates play an important role in the chemical communication between plant roots and the root microbiome. In 2022 we engaged in the Horizon Europe project “Breeding for coffee and cocoa root resilience in low input farming systems based on improved rootstocks”. In this project we will collaborate with CIRAD and e.g. partners in Uganda, Nicaragua and Vietnam to decode the root microbiome taxonomic and functional composition of coffee genotypes grown at different geographic locations and under different cultivation conditions. With our research we aim to provide a rational basis for developing sustainable microbiome-based strategies for coffee cultivation systems.

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Arbuscular Mycorrhizal Fungi (AMF) Associations of Robusta Coffee (*Coffea robusta*) across a Management Intensity Gradient in the DR Congo using Illumina Sequencing

Broeckhoven Ieben[1, 2] (ieben.broeckhoven@kuleuven.be), Honnay Olivier[2, 3], Merckx Roel[1, 2], Verbist Bruno[1]

[1] *Dep. of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium* ; [2] *KU Leuven Plant Institute, Leuven, Belgium* ; [3] *Dep. of Biology, KU Leuven, Leuven, Belgium*

Rationale:
The market share of robusta coffee is increasing. However, essential knowledge of robusta is lacking. AMF are known to play a crucial role in nutrient uptake, pathogen defense, and drought tolerance [1]. Understanding the associations between AMF and coffee, remains limited, especially for robusta. This study examines mycorrhizal diversity and community composition in robusta across different coffee systems (forest coffee, agroforestry and monocultures). It is the first of its kind in Robusta's centre of origin, DR Congo. This research aims to provide valuable insights into the associations between AMF and robusta, thus contributing to the potential development of sustainable coffee production practices.

Methods:
The research was carried out in Tshopo Province, DR Congo. A stratified random sampling design was used: monocultures, agroforestry and forest coffee systems. 25 plots were inventoried per coffee system, with 4 coffee plants per plot, resulting in 300 root samples. Genomic DNA was extracted from dried roots obtained. The 18S SSU rDNA region was amplified and Illumina sequenced. The data was processed using the USEARCH pipeline. Taxonomy assignment was accomplished by BLASTing against MaarjAM and GenBank databases. AMF richness was determined. Hill numbers were compared. AMF community similarities were analyzed using NMDS. Indicator species were identified.

Results:
After Illumina sequencing, a total of 6,105,071 sequences were recovered, which were allocated to 540 OTUs. Multiple AMF families (*Acaulosporaceae, Gigasporaceae, Glomeraceae*, …) and genera (*Acaulospora, Glomus, Scutellospora, …)* were identified. Mycorrhizal diversity varied across coffee systems, showing differences at both the family and OTU levels. Diversity decreased along the management intensification gradient from forest coffee to monocultural systems. Significant differences were observed in AMF communities among the three coffee systems.

Conclusions & Perspectives:
Our study revealed large differences in mycorrhizal diversity and community composition in *Coffea robusta* across coffee systems. Diversity decreased and community composition underwent notable changes from forest coffee to agroforestry and monocultures. This emphasizes the exceptional value of wild robusta in forest coffee systems due to its unique mycorrhizal associations. Safeguarding wild robusta populations in the DR Congo, its center of origin, holds potential for future applications in enhancing coffee yield. Further research is needed to understand the drivers behind these divergent AMF associations across coffee systems and establish the link between mycorrhizal diversity and plant productivity.

References:

1. Smith SE and Read DJ, Mycorrhizal symbiosis, 2008, 815 p.

S1-O-02

Selection for high yield, cup-quality and bean composition in coffee using Multi-trait Genotype-Ideotype Distance Index

Aberkane Hafid[1] (hafid.aberkane@rd.nestle.com), Blaszko Sebastien[1], Michaux Stephane[1], Ged Claire[1], Cango Jaime[2], Guato Jefferson[2], Nader Nieto Anna Camila[1], Arigoni Fabrizio[3], Herrera Pinilla Juan Carlos[1]

[1] *Nestle Institute for agricultural sciences, Plant science unit, NESTLE, Notre-Dame-D'Oé, France* ; [2] *Nestle Institute for agricultural sciences, NESTLE, Chollo, Ecuador* ; [3] *Nestle Institute for agricultural sciences, Plant science unit, NESTLE, Lausanne, Switzerland*

Rationale:
In coffee breeding, yield is often the main driver for the selection of new varieties even if other traits like bean characteristic or cup quality, remain also important, which explains the importance of systematic testing of new coffee selections for physical, chemical and sensory attributes. Using multi-trait analysis would allow breeders to increase the gain by selecting for multiple traits simultaneously. Recently, the Multi-trait genotype-ideotype distance Index (MGIDI) was proposed to select genotypes combining high performance across many traits. Applying this approach can improve selection for quality and identify the strength and weakness of coffee varieties.

Methods:
Two trials were established In Ecuador to evaluate 22 *C. canephora* and 18 *C. arabica* genotypes. The genotypes were assessed for the agronomic performance using yield and related traits. Bean composition (caffeine, trigonelline and total free sugar) was analyzed using Near Infrared Models and sensory attributes were assessed by a panel (comparative cupping). Green coffee yield was analyzed across the years using linear mixed models, and MGIDI was calculated for quality attributes considering the different traits with a selection intensity of 25%. Desirable and undesirable traits for each species were defined before validating the MGIDI.

Results:
The highest yield in Arabica was obtained by Star3 and Star1 which yielded more than 3t/ha. The MGIDI analysis identified six genotypes as best candidates for quality in Robusta and four in Arabica. Interestingly, the sensory traits were correlated differently between the Arabica and the Robusta varieties. The selection was done based on the MGIDI ranges estimated for Robusta (2-5.62) and Arabica (1.89-5.21). For Arabica, low trigonelline and bitterness contributed to the selection of H105 among the best, while H121 and Star 2 had better aromatic profile low caffeine content. In Robusta, the selection was mostly driven by low caffeine (CL74), better aroma and total free sugars (Roubi8), and a better body with low trigonelline content (Roubi7 and Roubi9).

Conclusions & Perspectives:
Our results showed the potential of MGIDI to combine different traits, facilitating the selection for multiple quality attributes in the selected coffee varieties. Future applications of MGIDI approach include assessing the effect of other traits (e.g. bean size) but also, the effects of the environment and the post-harvest process on bean quality. Our approach has led to the selection of high performing coffee varieties with high cup quality some of which have been registered and are being distributed in various producing countries.

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S1-O-03

Transcriptional control of the endosperm maturation program and galactomannan cell wall deposition in *Coffea* species

Joet Thierry[1] (thierry.joet@ird.fr), Stravinides Anna[1], Vaissayre Virginie[1], Combes Marie-Christine[1], Serret Julien[1], Morcillo Fabienne[2], Dechamp Eveline[2], Etienne Hervé[2], Lashermes Philippe[1], Dussert Stéphane[1]

[1] *DIADE, IRD, Montpellier, France* ; [2] *DIADE, CIRAD, Montpellier, France*

Rationale:
Seeds of *Coffea*species are albuminous, comprising a tiny embryo encapsulated in a copious living cellular endosperm. As in most albuminous seed species, the main storage carbohydrate of coffee seeds is not starch but polysaccharides of the mannan family that are deposited in the cell walls of the endosperm. To date, little information is available regarding the specific regulatory mechanisms that govern galactomannan biosynthesis and cell wall deposition in albuminous seeds.
Methods:
To gain insight in the coffee seed maturation program, we built a gene coexpression network using a large RNA-seq dataset (14 *Coffea* species × 5 endosperm developmental stages) and a pathway-guided strategy.
Results:
The network revealed tight transcriptional coordination of the core galactomannan biosynthetic machinery with sucrose import and cleavage, glycolysis, fatty acid synthesis, and cellulose biosynthesis. It also showed a concerted regulation of the transfer of nucleotide sugars to the Golgi apparatus, where galactomannan assembly occurs, the trans-Golgi network machinery for delivery of polysaccharides to the cell wall, and enzymes required for their post-deposition modification. The transcription factors FUS3, WRI1, SHN2 and DREB2D appeared as the major regulators of the coffee endosperm maturation program. DREB2D was the only direct partner of the core-galactomannan biosynthetic genes. Molecular genetics approaches further confirmed that DREB2D plays a critical role in nucleotide sugar homeostasis and cell wall polysaccharide metabolism, and triggers part of the seed maturation program when overexpressed in *Coffea arabica* somatic embryos.
Conclusions & Perspectives:
These findings shed light into the specific regulatory mechanisms that govern cell wall storage polysaccharides synthesis and regulate the coffee seed maturation program.

S1-O-04

Genetic diversity and structure of *Coffea arabica* and *Coffea racemosa* in Mozambique

Tapaça Inocência da Piedade Ernesto[1] (inoctapaca@gmail.com), Mavuque Lopes[2], Corti Riccardo[3], Pedrazzane Samuele[3], Maquia Ivete S. A.[4], Tongai Castigo[5], Partelli Fábio Luís[6], Ramalho José Cochicho[7], Marques Isabel[8], Ribeiro-Barros Ana Isabel[8]

[1] *Instituto Superior de Agronomia, Lisbon, Portugal, Lisbon* ; [2] *3 Unilurio, Faculty of Agricultural Sciences Campus de Unang, EN733 Km 42, Unan, Lichinga-Mozambique, Lichinga, Mozambique* ; [3] *Facoltà di Agraria, Università degli studi di Firenze, Piazzale delle Cascine 1, Italy, Italy* ; [4] *Biotechnology Center, Eduardo Mondlane University, Km 1.5, Maputo P.O. Box 3453, Maputo-Mozambique, Mozambique* ; [5] *Department of Scientific Services, Gorongosa National Park, Gorongosa P.O. Box, Sofala-Mozambique, Mozambique* ; [6] *Centro Universitário do Norte do Espírito Santo (CEUNES), Departmento Ciências, Brazialian, Brazil* ; [7] *Unidade de Geobiociências, Geoengenharias e Geotecnologias (GeoBioTec), Faculda, Lisbon, Lisbon* ; [8] *Forest Research Center (CEF), Associate Laboratory TERRA, Instituto Superior de, Lisbon, Portugal, Lisbon*

Rationale:
The impact of climate change in the coffee value chain is undeniable. Considering the vulnerability of the two mainstream species, *Coffea arabica* and *Coffea canephora*, to extreme weather events, as well as the narrow genetic plasticity of the commercial cultivars, the introduction of wild-relatives and underutilized species is essential for the sustainability of the sector. In this work, we have assessed the occurrence of *Coffea* species in Mozambique (southern Africa) to understand the extent of genetic erosion between wild and cultivated species.
Methods:
Plastid-based markers (*rbcL* and *matK*), Single-sequence polymorphic repeats (SSR), and Single nucleotide polymorphisms (SNPs) generated by Genotype-by-Sequencing (GBS) were used to characterize 35 samples of *C. arabica* (27 from Gorongosa, Sofala province; 8 from Niassa province), and 48 wild relatives (Maputo, Inhambane, and Sofala provinces) [1].
Results:
Only one wild species was found, *C. racemosa*, with a high level of genetic separation from *C. arabica*. *C. arabica* presented low levels of diversity likely related to its autogamous nature, while the allogamous *C. racemosa*presented higher levels of diversity and heterozygosity. The analysis of the functional pathways based on SNPs suggests that the stress signaling pathways are more robust in this species.
Conclusions & Perspectives:
Given the global socioeconomic importance of coffee, it is vital to innovate the coffee value chain, introducing more resilient species, increasing genomic diversity, and adopting climate-smart practices.

Acknowledgements: This research was funded by Camões, Instituto da Cooperação e da Língua (CICL), Agência Brasileira de Cooperação (ABC), and Parque Nacional da Gorongosa (PNG), under the Triangular Project TriCafé (GorongosaCoffee), and by Fundação para a Ciência e a Tecnologia, I.P. (FCT) through the research units UIDB/00239/2020 (CEF) and UIDP/04035/2020 (GeoBioTec), and Scientific Employment Stimulus—Individual Call (CEEC Individual) 2021.01107.CEECIND/CP1689/CT0001 (IM).

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ABSTRACTS WEDNESDAY 13 SEPTEMBER

ORAL PRESENTATIONS

SESSION 5:
Climate change - Sustainability - Labels

&

SESSION 3:
Farm management

S5-O-05

Results of a TEEB AgriFood project evaluating the sustainability of public policy scenarios in the coffee sector in Mexico

Manson Robert (robert.manson@inecol.mx)

Functional Ecology Network, Instituto de Ecología, A.C., Xalapa, Veracruz, Mexico

Rationale:
Traditional agricultural evaluations rely on simple economic analyses of costs (labor + materials) and earnings (production x prices), and largely ignore the potential benefits (biodiversity conservation and ecosystem service provisioning) and costs (contamination and human health and well-being) of specific management strategies. TEEB AgriFood(1) seeks to address these concerns through an integrated approach quantifying reserves and flows between natural, human, social, and produced capital under different public policy scenarios, and has been applied in a variety of production systems world-wide. Our goal was to apply this methodology for the first time to shade coffee in Mexico, a sector suffering from climate change, low production, and high margination within farmer communities.

Methods:
We selected 11 coffee regions in the four most important coffee growing states in Mexico accounting for 92% of production and 83% of farmers. Through a combination of mining of national data bases and selective field work in each region, our interdisciplinary team quantified reserves of each capital and key flows between them at a sub-municipal scale. Using consultations with key actors in the coffee sector we developed three policy scenarios, each including the potential impacts of climate change, and then evaluated their potential impacts in 2045 using a Bayesian modeling approach: 1) business as usual with no changes in current policies, 2) a focus on increasing production through renovation with high-yield, rust-tolerant, varieties, and 3) a focus on strengthening differentiated coffee including certification, specialty coffee, and agricultural diversification.

Results:
No one strategy maximized sustainability and helped growers adapt to the challenges of climate change, rather reserves of capitals were maximized through an approach that combined different management options to increase production and net earnings (produced capital) with neutral or positive effects on other capitals. An exclusive focus on increasing production resulted in increased earnings initially but this benefit decreased as the effects of climate change increased. Conversely, premiums from coffee certification alone did not optimize sustainability due to lower coffee productivity.

Conclusions & Perspectives:
TEEB AgriFood is a useful tool for highlighting policy options that could ensure sustainable coffee production in a world dominated by climate change. However, this approach may be limited in many countries including Mexico by the lack of robust monitoring of prices, costs of production, and the multi-dimensional effects of public programs in the agriculture sector.

References:

1. https://teebweb.org/our-work/agrifood/

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'Beyond the chain': landscape approaches to sustainability in the coffee sector

Neilson Jeffrey[1] (jeffrey.neilson@sydney.edu.au), Bienabe Estelle[2], Tran Thi Minh Ngoc[3]

[1] *University of Sydney, Darlington, NSW, Australia* ; [2] *CIRAD, Montpellier, France* ; [3] *World Agroforestry Research Centre, Hanoi, Vietnam*

Rationale:
Livelihoods and environments in coffee-producing regions are increasingly affected by various modes of social and environmental governance enacted by large coffee companies along global value chains (Grabs, 2020). It is therefore important to understand the shifting sustainability strategies of leading coffee firms (Ponte, 2019). For the last two decades, such governance was dominated by third-party sustainability standards, whereby individual farms within particular supply chains were audited for their compliance to farm-level standards (Dietz et el., 2021). There are, however, indications that new mechanisms may be emerging that extend "beyond the chain" to operate at landscape scales.
Methods:
This research commenced with a content analysis of publicly available documents and reports from the top ten global coffee roasters. The primary material consisted of annual reviews, corporate sustainability reports, corporate social responsibility (CSR) reports, environmental and supply chain policy documents, primary websites, and media releases. 90 documents were selected for analysis, and reviewed for specific initiatives, sustainability themes, and governance mechanisms. This content analysis was then complemented with initial field observations and stakeholder interviews in Vietnam.
Results:
Corporate sustainability strategies are exerting a powerful influence well beyond their immediate supply chains. Our analysis resulted in a five-fold typology of corporate governance mechanisms for sustainability: i) direct action by lead firms; ii) empowerment of traders as agents of change; iii) use of supply chain standards; iv) engagement with development agencies and NGOs; and v) public-private partnerships. Our findings provide evidence for the heightened engagement by lead firms beyond the chain and into the broader production landscape.
Conclusions & Perspectives:
We are seeing lead firms attempt to address sustainability-related challenges by trying to tackle problems of inequality, environmental degradation, and community improvement (e.g. through healthcare and educational initiatives). Mechanisms that involve more wide-ranging engagement with producing landscapes, and enrolling multiple actors within those landscapes, are on the ascendancy, thus contributing to a phenomenon of commodity-centric landscape governance. While this development suggests a heightened lead firm influence over livelihoods and environments in coffee-producing regions, the implications and effectiveness of this development require further research.

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S5-O-07

What roles sustainability standards and programs play in coffee Robusta smallholders' capacity to harness the shift to quality in Vietnam?

Tran Thi Minh Ngoc[1] (t.ngoc@cifor-icraf.org), Bienabe Estelle[2]

[1] *International Centre for Research in Agroforestry (ICRAF), Hanoi, Vietnam* ; [2] *International Centre for Research in Agroforestry (ICRAF); French Agricultural, Hanoi, Vietnam*

Rationale:
In the last 20 years, coffee traders, roasters and retailers have significantly invested in sustainability standards and programs (SSP) to answer environmental and societal concerns (Elder, S. D., Lister, J., & Dauvergne, P., 2014). Recently, demands for high quality and specialty coffee are permeating Robusta coffee markets offering promising pathways for suppliers from developing countries (CBI, 2022); and quality improvement and producers' awareness of sales requirements are increasingly materializing in response to these trends. However, despite Vietnam leading position worldwide constituting up to 40% of Robusta coffee production and having widely implemented SSP (certified coffee represents about 26% of total coffee area), it only ranks 10th in value (IPSARD, 2023).

Methods:
Coffee value chain surveys were conducted with small producers (n=121), middlemen (n=33), and input providers (n=20) using semi-structured questionnaires. Cluster sampling was applied for farmers including (1) those participating to export trader sustainability program (SP) (n=82); and (2) those who do not (n=39), as well as screening criteria to ensure ethnic minority and gender participation. Surveys were complemented by key informant interviews with supporting actors (District Agricultural Department, Commune People Committees), participant observation, and secondary data (including local public reports and decisions).

Results:
Though clear differences were observed between SP and non-SP farmers in production practices (notably more efficient input uses) and quality requirements awareness, overall farmers' lack proper understanding of essential quality requirements (incl. foreign matters, defective beans, moisture) and lack of control on farm drastically affect their bargaining power with middlemen. Importantly though, new inroads into improved quality management at farmer level emerge through cooperatives supported by traders moving into high quality segments. These are particularly worth exploring in light of low premium for sustainable certified coffee compared to possible value addition observed for high quality Robusta coffee [1].

Conclusions & Perspectives:
While SSP have brought positive changes in coffee farming practices and environmental protection, they are so far much less effective in helping farmers to harness the value addition potential of the quality shift. Innovative initiatives led by coffee players to support farmers' group and cooperatives in upgrading quality (incl. addressing chain transparency) could be highly complementary to these. Their potential to better address farmers' livelihoods needs represents an important area of further research.

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S5-O-08

Connecting Geographical Indication (GI) and sustainable practices with Hindu Philosophy Tri Hita Karana in the island of Bali

Fabianus Reza[1] (reza.fabianus@gmail.com), Fournier Stephane[2], Rival Alain[3], Arizal Irfaan[4], Pulih I Ketut[5]

[1] *National Coop, Ministry of Cooperatives & SMEs Republic of Indonesia, Jakarta, DKI Jakarta, Indonesia* ; [2] *UMR Innovation, Institut Agro, Montpellier, France* ; [3] *Cirad Indonesia, Jakarta, DKI Jakarta, Indonesia* ; [4] *Big Data, Coop Coffee Indonesia, Denpasar, Bali, Indonesia* ; [5] *Abian Subak Tri Guna Karya, CGIP Kopi Arabika Kintamani Bali, Kintamani, Bali, Indonesia*

Rationale:
Balinese coffee growers are strongly committed to the cultivation of coffee in accordance with the principles of the Hindu philosophy of Tri Hata Karana. The Government of Indonesia also launched its ambitious Green Economy Index (GEI) Target aiming for a Net-Zero Emissions. Coop Coffee is a co-operative company with 1,214 coffee growers from the Kintamani Bali coffee Geographical Indication (GI) zone. Coop Coffee wants to reduce greenhouse gas emissions throughout the coffee chain.

Methods:
The project uses two complementary tools: a technology capable of estimating and reducing GHG emissions together with the GI certification scheme. A blockchain technology is being implemented.

Results:
Preliminary research involving 10 producers succeeded in controlling two main sources of GHG emissions: the organic decomposition of wastewater and the coffee pulp. This effort is supported by Starbucks Company who installed a roasting plant in Bali.

Perspectives:
Coop Coffee's ambition is to develop carbon-smart agriculture to support innovation on carbon sequestration. The ultimate goal is to comply with the Tri Hita Karana together with accessing to economic benefits such as 'carbon premiums'.

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S3-O-01

Evaluating water requirements of Robusta coffee trees to reduce irrigation

Rigal Clément[1, 2] (clement.rigal@cirad.fr), Hoang Trung Quôc[3]

[1] *UMR Absys, CIRAD, Montpellier, France* ; [2] *ICRAF, Hanoi, Vietnam* ; [3] *WASI, Buon Ma Thuot, Vietnam*

Rationale:
Vietnam is the largest producer of Robusta coffee worldwide, with more than 600,000ha of coffee farmlands in the Central Highlands. Most of these farming systems are irrigated during the dry season to trigger synchronous flowering and to sustain coffee physiological processes until the onset of the rainy season. However, there are concerns that the current national recommendation of 400L/coffee tree/round, with 2 to 5 rounds of irrigation per year based on weather conditions, may overestimate the water needs of coffee trees, leading to unnecessary depletion of underground water resources in the dry season. This study thus aims to assess the minimum amount of water needed to sustain coffee needs in the Central Highlands.

Methods:
A trial was set up in 2021 in Dak Lak Province within an existing coffee farm intercropped with avocado trees. The experiment employed a split-plot design incorporating 2 factors: irrigation quantity (400L/round vs. 250L/round) and coffee system (monoculture – achieved through avocado tree removal – vs. agroforestry). Sapflow sensors measured coffee transpiration from January to May 2023. Pre-dawn leaf water potential measurements were conducted before each irrigation round to assess hydric stress. Complementary measurements of soil moisture sensors were taken to a depth of 60cm, providing insights into the water availability for coffee trees.

Results:
In monoculture systems, coffee trees under 250L and 400L irrigation exhibited similar transpiration rates and leaf water potentials from January to March. Differences emerged in April, towards the end of the dry season, when coffee trees under 250L irrigation displayed reduced transpiration rates and higher hydric stress compared to those receiving 400L irrigation. In agroforestry systems and throughout the dry season, coffee trees used 25-33% less water than in monoculture systems. Irrigation had no significant impact on transpiration and leaf water potentials. Following the onset of the rainy season in May, all coffee trees quickly recovered from hydric stress.

Conclusions & Perspectives:
This study indicates that 250L irrigation is adequate to meet the water demand of coffee trees in monoculture systems at the beginning of the dry season. However, as the dry season extends and temperatures rise, this amount is no longer sufficient. Conversely, coffee trees under shade trees require less water and are not impacted by reduced irrigation treatments. These findings highlight that that the ongoing shift from monoculture coffee to coffee-agroforestry systems based on fruit trees can result in substantial reductions in water consumption for irrigation purposes.

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S3-O-02

Contrasted agronomical and physiological responses of five *Coffea arabica* genotypes under soil water deficit in the field in Northwest of Vietnam

Sarzynski Thuan[1] (thuan.sarzynski@ecomtrading.com), Vaast Philippe[2], Marraccini Pierre[3], Etienne Herve[4], Rigal Clement[5], Nguyen Hai[6], Nguyen Chang[7], Ngoc Quyen[8], Nguyen Hung[7]

[1] *DIADE, CIRAD, Ho Chi Minh, Vietnam* ; [2] *Eco&Sols, CIRAD, Cali, Colombia* ; [3] *DIADE, CIRAD, Kampala, Uganda* ; [4] *DIADE, CIRAD, Montpellier, France* ; [5] *Absys, CIRAD, Montpellier, France* ; [6] *NOMAFSI, Phu Thp, Vietnam* ; [7] *NOMAFSI, Son La, Vietnam* ; [8] *NOMAFSI, Phu Tho, Vietnam*

Rationale:
Several models predicted that climate change will increase drought stress on coffee cultivation and decrease its growth and yield worldwide. As a potential adaptation solution against these adverse environmental conditions, breeding programs have developed high-yielding new *Coffea arabica* F1-hybrids adapted to agroforestry systems. However, the response to drought of these F-1 hybrids has never been assessed.

Methods:
The study was carried out at NOMAFSI research station in Son La province (annual average temperature ± 21°C, annual rainfall ±1500 mm) of Northwest Vietnam at an elevation of 780 m.a.s.l at the edge of the coffee belt. Growth, yield and physiological responses of five *C. arabica* genotypes (2 fixed lines: Catimor [C] and Marsellesa [M] and 3 hybrids: Starmaya [HS], Centroamericano [H1] and Mundo Maya [H16]), shaded by the leguminous shade tree species *Leucaena leucocephala*, were assessed under a rain-fed (Cont) and a rain-suppressed treatment (WS) which reduced soil water content by 14% over 2 successive years of production.

Results:
In Cont, production of H16, H1 were higher than HS, M or C due in part to their capacity to maintain high photosynthesis. Under water deficit (WS treatment), the yield of C, M, HS, H1 and H16 genotypes decreased respectively by 25, 16, 54, 75 and 20% compared to rain fed. Hybrids are more vigorous and produce more than the local Catimor under rain-fed agroforestry conditions. However, tolerance to water deficit is not systematically associated with hybrid vigor. Indeed, only the F1 hybrid H16 was the best performing genotype in both rain-fed and rain-suppressed conditions and displayed a high photosynthesis at times of high evaporative demand (11AM, 2PM), as well as a high yield and high fine root production in conditions of soil water deficit. Fixed lines (C and M) had a low yield but were not significantly affected by drought unlike HS and H1 whose high yield strongly decreased under water stress.

Conclusions & Perspectives:
Our better understanding of the physiological and agronomical response of these genotypes to soil water deficit will enhance coffee breeding and genotype selection for drought tolerance as a climate smart solution for resilient coffee agroecosystems. This work shows the potential of breeding productive and drought tolerant genotypes among the highly F1 Arabica hybrids for agroforestry systems.

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S3-O-03

Root traits and biomass productions of drought resistant and susceptible arabica coffee varieties growing under contrasting watering regimes

Adem Mohammed Worku[1] (mohaworku@gmail.com), Aman Mohammed[2], Shimbir Tesfaye[3], Astatkie Tessema[4]

[1] *Deparment of Horticulture and Plant Sciences, Jimma University, Jimma, Ethiopia* ; [2] *Coffee agronomy and Physiology, Jimma Agricultural Research Centre, Ethiopian Institute of Agricultural Research, Jimma, Ethiopia* ; [3] *Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia* ; [4] *Faculty of Agriculture, Dalhousie University, Truro, Canada*

Drought stress is currently becoming a major factor affecting coffee production. This study examined root trait and biomass yield variations between drought-resistant (74110, Angefa, Bultum, Chala and Gawe) and drought-susceptible (75227, Koti, Melko CH2, Menasibu and Mokah) varieties of arabica coffee seedlings growing under contrasting watering-regimes (Well-watered and Not-watered) for 30 days followed by 15 days re-watering (recovery). The research was carried out in a split-plot design with three replicates where Watering-regime was the Main-plot factor and Variety was the Sub-plot factor. In both water-stress and recovery periods, Watering-regime*Variety interaction significantly affected all measured root traits, except tap root length (TRL) and lateral root length (LRL) in the stress period and specific root length (SRL) and root density (RD) in the recovery period. Compared to the other watering-regime and variety combinations, (1) tap root diameter (TRD), lateral root number (LRN) and root volume (RV), and (2) LRN, specific root length (SRL), root-mass ratio (RMR), root-shoot ratio (RSR) and root angle (RA) were higher for 74110 and Bultum, respectively under Not-watered condition. Root length density (RLD), RA, RMR and RSR were also higher for Angefa, Chala and Gawe under Not-watered condition. In both study periods, significantly lower fresh and dry weights of coffee seedlings observed for Not-watered condition than for Well-watered condition. Overall, the findings of this study highlighted the existence of higher root trait variations among arabica coffee varieties growing under contrasting watering regimes. This potential can be exploited for mitigating the effects of drought on coffee production.

KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 7:
Roasted coffee Technology & Processing

S7-KN

Expanding the flavour space of coffee: Impact of Species, Processing and Roasting

Opitz Sebastian E. W. (opit@zhaw.ch), Khushvakov Jaloliddin, Lipp Oliver, El Khouri Aviel, Wernli Nicolas, Smrke Samo, Yeretzian Chahan

Analytical Chemistry unit and Coffee Excellence Center, Zurich University of Applied Sciences, Waedenswil, Switzerland

Rationale:
Due to increasing uncertainties about coffee production in the coming years, scientists and coffee experts have started to explore other *Coffea* species in search of improved adaptations to ongoing climate change, e.g. drought tolerance and rising temperatures. Another currently observed trend is a high enthusiasm among coffee producers to experiment with post-harvest processing protocols in order to increase the quality of coffee, e.g. with long fermentation times in the cherry, also known as carbonic maceration. These two trends are expanding the flavour space of coffee.

Methods:
We have used stable isotope dilution analysis gas chromatography coupled to mass spectrometry to quantify a set of important aroma compounds in five different coffee species of different roast levels as well as used gas chromatography coupled to olfactometry to identify relevant aroma compounds that are linked to fruity and floral notes in a high-end Arabica coffee. In addition, we have analysed a large set of green coffee samples with PTR-ToF-MS to assess the impact of poist-harvest processing on the volatile composition of green coffee.

Results:
All coffee species generate roast specific compounds, such as pyrazines, furans and pyrroles that are being formed with increasing roast degree. In addition, species specific as well as process specific aroma compounds contribute to a unique aroma of the three species *Coffea eugenioides*, *C. liberica* and *C. racemosa*, which clearly separates them from *C. canephora* and *C. arabica* coffee. This differentiation of both species-specific compounds as well as impact of post-harvest processing on the different roast levels will be discussed. In addition, hypotheses are proposed for the differing levels of aroma compounds and how these are related to the composition of green coffee, both in terms of volatile and non-volatile compounds.

Conclusions & Perspectives:
Upon roasting, also other coffee species (besides *C. arabica* and *C. canephora*) are able to produce coffee beverages that are appreciated by consumers. An increasingly sophisticated understanding of the importance of post-harvest processing will also spark even more interest from the coffee specialty scene and other coffee species will emerge as potential alternatives for coffee producers. However, none of these three species, *C. eugenioides*, *C. liberica* and *C. racemosa*, will be able to solve the predicted problem of a declining supply of Arabica coffee in the near future.

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S7-O-01

Controllability of the coffee roasting process

Botha Cila[1] (cila.botha@nwu.ac.za), Van der Merwe Frikkie[1], Uren Kenny[2]

[1] *School of Chemical and Minerals Engineering, North-West University, Potchefstroom, South Africa* ; [2] *School of Electrical, Electronic and Computer Engineering, North-West University, Potchefstroom, South Africa*

Rationale:
The coffee roasting process is both a science and an art, and artisan roasters are required to replicate roast profiles for different bean batches. Automating the process can assist artisans and trainees with quality control in producing different coffee roasts. It is not yet fully automated, creating a need for a viable control strategy enabling the development of a controller for modern batch rotating-drum roasting machines.

Methods:
A control strategy was developed for a rotating-drum batch roaster to replicate roast profiles. Experiments were done on a 6 kg capacity artisan coffee roaster using unwashed Arabica beans. The controllable time frame and controller parameters for the roasting process were determined. A relative gain array was used to identify the primary controlled variable, the rate of temperature change controlled by the gas flow to the burner. Experiments were performed at different prime temperatures (170-230°C) and the effect of manipulated variables was analysed. The controller parameters obtained experimentally were validated using simulated data. Various control strategies were investigated using IMC, Cohen and Coon, and ITEA-based parameter models for both PI and PID controllers. Simulink® was used to construct and analyse the models in conjunction with a validated model of the roasting process developed by Schwartzberg (2002). Bode plots confirmed the stability of the final controller.

Results:
The coffee roasting process is a lag-dominant first-order process with time delay which may be approximated as a pure integrating system for control purposes, with an average dead-time of 20 seconds. There is an initial time frame (90 s) during the roasting process that is uncontrollable as per Faanes (2003), Ziegler & Nichols (1943) and Skogestad & Postlethwaite (2001). This is due to the evaporative cooling during the roasting process's initial drying phase. The final control strategy recommends a single-input single-output (SISO) IMC-based PI controller that manipulates the gas flow rate to the burner to control the derivative of the roast profile to reach the continuously moving setpoint, which is determined by the desired roast profile.

Conclusions & Perspectives:
The uncontrollable 90 s corresponds to the turning point of the roast profile. To achieve control, the process should be forced past this turning point as early as possible. A simple IMC-based PI controller can replicate desired roast profiles in rotating-drum batch roasters during the controllable phase. To reduce the uncontrollable time frame, it is recommended to investigate the impact of rapid heat addition at the beginning of the process to expedite moisture removal.

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S7-O-02

Physical and Chemical Responses of Robusta Coffee Beans to Superheated Steam Roasting

Derossi Antonio[1] (antonio.derossi@unifg.it), Severini Carla[1], Caporizzi Rossella[1], Chindapan N.[2], Devahastin Sakamon[3]

[1] *Department DAFNE - Lab of Emerging Technology and Food Formulation, University of Foggia, Foggia, Italy* ; [2] *Siam University, Siam University, Thailand, Thailand, Thailand* ; [3] *Department of Food Engineering, King Mongkut's University of Technology Thonburi, Thailand, Thailand*

Rationale:
Roasting is a pivotal step in the coffee industry. It enables us to fully realize the nutritional and sensory potentials of green coffee beans. Roasting indeed triggers many chemical and physical changes, with benefits on the colour, flavour, aroma, volume/density, mechanical properties, and healthy characteristics. However, some compounds with potential negative effects, i.e., acrylamide and acrolein, could be generated during roasting. In practice, hot air (HA) in the temperature range of 150-210°C is the only method used for roasting. Here, we tested an innovative approach based on the use of superheated steam (SHS) as an oxygen-free roasting medium with remarkable heating ability as an alternative to hot-air roasting.
Methods:
Green Robusta coffee beans were submitted to HA roasting and innovative SHS roasting at 210, 230 and 250°C. Preliminary experiments allowed to define, for both methods, the roasting times to get light, medium, and dark coffee beans. The evolutions of the coffee beans bed temperature and color parameters during roasting were described. Also, the main chemical compounds, e.g. sugars, acids, antioxidants, as well as acrolein content, acrylamide content and polycyclic aromatic hydrocarbons (PAHs) were measured using internationally recognized methodologies.
Results:
Superheated steam exhibited the ability to reduce the formation of acrylamide, especially for the experiments at a higher temperature, i.e., 250°C, for which a decrease to 16% for medium coffee beans and to 25% for dark coffee beans, was observed. Similarly, a decrease of 60-65% of PAHs was observed when using the higher temperature. SHS roasting at higher temperatures could be preferred for its ability to hamper the formation of undesired unhealthy compounds in roasted coffee.
Conclusions & Perspectives:
SHS is an interesting novel roasting method by which the overall healthy properties of the roasted coffee benefitted. This was clearly observed for roasting at higher temperatures. Our results fuel the interest for further experiments aimed at better understanding the effects of SHS on the physical properties of the beans, e.g., microstructure, volume/density, texture properties, on the grinding as well as on the physical, chemical and sensory properties of brews prepared to adopt different brewing methods. We are currently testing the quality of espresso coffee obtained using HA and SHS roasted coffee beans.

S7-O-03

Digital Twin-Assisted Optimization of the Coffee Roasting Process

Tück Sebastian[1] (s.tueck@probat.com), Flüthmann Noah[1], Schmidt Dominik[2], Lindemann Bernd[3], Velten Kai[2], Koziorowski Thomas[1]

[1] *Research and Innovation, PROBAT AG, Emmerich am Rhein, Germany* ; [2] *Institut für Modellierung und Systemanalyse, Hochschule Geisenheim University, Geisenheim, Germany* ; [3] *Institut für Lebensmittelsicherheit, Hochschule Geisenheim University, Geisenheim, Germany*

Rationale:
Over the last two decades, simulating the coffee roasting process has been a focus of research worldwide [1-3]. However, industry implementation has been sparse due to assumptions of constant supply temperatures and flow rates. To address this, we propose a digital twin that utilizes data already available in every roastery.

Methods:
Our digital twin consists of three interconnected models. The first model is the roaster flow state model, which establishes a link between actuator positions and flow rates for a given roasting machine. This model needs to be adapted to the specific roasting machine being used. The second set of models focuses on the physio-chemical behavior of coffee beans during roasting, including drying kinetics, heat generation, and roast loss. These models are adapted to the coffee variety being roasted and rely on data that is already present in the roastery. The development of these sub models involved a combination of existing literature and experimental data. The third model provides heat transfer coefficients derived from both computational fluid dynamics (CFD) simulations and measurements. These models are universally valid. By combining these three models, we can solve the energy balance and determine the energy transfer between the supply gas, the roaster, and the coffee beans during roasting. This allows us to predict the roasting curve, as well as the moisture and organic loss during roasting.

Results:
When optimizing coffee roasting models for six diverse batches simultaneously, the predictions of the respective roasting curves had a maximal error ranging from 1.5% to 2.9%, and a root mean square error (RMSE) of 0.6% to 1.4%, while accurately predicting both moisture and organic loss. However, the maximal temperature error was most frequently observed at the end of the roasting process, where the model tended to underpredict the temperature, indicating a need for further improvements in accounting for exothermic heat generation. Most importantly, the model provided novel insights into heat flow inside the roaster, which significantly deepened our understanding of the roasting process using the specific roasting machine.

Conclusions & Perspectives:
The digital twin enables energy-optimized recipes and control systems and facilitates the transfer of recipes between different roasting machines by accounting for machine differences through the prediction of the common denominator - energy transfer. Thus, our model holds significant potential for application in the roasting industry.

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S7-O-04

A new rugged photoionization mass spectrometer for on-line process analysis in industrial coffee roasting

Zimmermann Ralf[1] (ralf.zimmermann@uni-rostock.de), Heide Jan[1], Czech Hendryk[1], Ehlert Sven[2], Koziorowski Thomas[3], Walte Andreas[2]

[1] *Chair of Analytical Chemistry, University of Rostock, Rostock, Germany* ; [2] *Photonion GmbH, Schwerin, Germany* ; [3] *Probat GmbH, Emmerich, Germany*

Rationale:
The coffee roasting process is a crucial step for generation of high-quality coffee, as roasting conditions and profiles significantly affect the flavor, aroma, and color of the final products. The traditional method for coffee roast monitoring relies on temperature evolvement, off-line quality control, subjective evaluation and other simple monitoring approaches. However, these monitoring methods are rather imprecise, time-consuming, labor-intensive, and prone to errors. Additionally, most traditional methods are out of the time-frame of the process itself (i.e., off-line analysis). To address these limitations, a novel instrument based on the on-line photoionization mass spectrometry technology was developed. The systrem is specifical designed for coffee roasting process monitoring and process development in the food industry.

Methods:
A new photoionization orthogonal acceleration time-of-flight mass spectrometry (PI-TOFMS) process analyzer was developed. By coupling a industry high-frequency excimer laser (for detection of aromatic species by Resonance-Enhanced MultiPhoton Ionization, REMPI) and a VUV-discharge lamp (for detection of aliphatic species by Single Photon Ionization, SPI) to a TOFMS, we have developed a robust setup for industrial usage, that is capable of real-time monitoring of the coffee roasting process. The tool is the first of its kind and offers a large linear range. The photoionization process can be tuned to target compounds and is well-suited for monitoring the chemical changes that occur during the coffee roasting process.

Results:
The newly developed PI-TOFMS process analyzer system was tested under real world conditions in an industrial coffee roasting facility, where it was coupled to an industrial drum roaster and monitored roast batches of an extended time. The oaTOF-MS system is very robust and reliable even in the harsh conditions of all-day industrial production. In addition to basic roasting properties such as the roast degree/color values also specifics information as, e.g., the occurrence of Robusta contaminations in pure Arabica labeled coffees can be obtained.

Conclusions & Perspectives:
The PI-TOFMS process monitoring system provides detailed real-time information on the chemical changes occurring during coffee roasting and thus on the process-related added value. The on-line mass spectrometry approach this is a promising improvement over traditional process steering methods, enabling a new form of quality control as well as roast recipe development and therefore a more efficient and sustainable production.

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KEYNOTE LECTURER & ORAL PRESENTATIONS

SESSION 6:
Biochemistry & Biotechnology of green coffee

&

SESSION 4:
Green coffee processing

S6-KN

Keynote lecturer

Transmuting coffee by-products into eatable and non-eatable products

Farah Adriana (afarah@nutricao.ufrj.br)

Núcleo de Pesquisa em Café Prof Luiz Carlos Trugo- NUPECAFÉ, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Food systems (from farm to fork and disposals) are responsible for about a third of anthropogenic greenhouse gas (GHG) emissions (1). In turn, the agricultural sector is negatively impacted by GHG and climate change (2), facing the challenge of emissions reduction through sustainable practices and having to produce more food due to the continuous world population growth, projected to reach nine billion in 2050 (3). At the same time, the incidence of obesity and degenerative diseases also continuously increases, demanding changes in the quality of dietary patterns that favor the intake of more plant foods with antioxidant and anti-inflammatory properties.

According to the Food and Agriculture Organization (FAO), a sustainable food system contributes to food security and nutrition for all so that the economic, social, cultural, and environmental bases to generate food security and nutrition for future generations are safeguarded (4). New types of foods are being presented as alternative ways to ensure food security. However, controlling waste is a priority. Food waste, including by-products, can be a relevant source of nutrients and bioactive compounds, delivering several benefits to health and aggregating value to the production chain.

Coffee is one of the major food commodities in the world. The annual production of about ten million tons generates a large amount of waste material of excellent quality, which is convertible into healthy products. Additionally, the amount of celluloses, lignin, and other insoluble or leftover components contained in the spent grounds and low-grade defective beans offer several possibilities of use other than just as biofuel.

In this presentation, we will approach the use of coffee by-products as a means for sustainable health promotion and value addition to the coffee production chain.

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S6-O-01

Prevalence of mycotoxigenic fungi and Ochratoxin A in green coffee beans (*Coffea arabica* L.)

Hagos Legese[1] (legehagos@gmail.com), Guta Meseret[2], Bacha Ketema[2]

[1] *Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia* ; [2] *Jimma University, Jimma, Ethiopia*

Rationale:
Coffee is one of the highly preferred international beverages and the most important traded commodities in the world next to petroleum (FAO, 2015). It is the most important export commodity for Ethiopia and it accounts for about 34% of value of all exports (FAS, 2019). Ethiopia is the largest coffee producer in Africa & 5th in the world next to Brazil, Vietnam, Colombia and Indonesia. It covers about 7.4% of total world coffee production (FAS, 2019).
Methods:
A total of 77 coffee samples were collected from Mana, Goma, Gera and Limu Kosa districts of Jimma zone, Oromia Regional State of Ethiopia. Malt Extract Agar (MEA) was used for isolation and identification of fungi using macro and microscopic characteristics and HPLC was used to detect and quantify of Ochratoxin A in green coffee bean.
Results:
Different fungal genera, including: *Aspergillus*, *Fusarium*, *Penicilium* and *Rhizopus*were found associated with coffee beans from different coffee processing methods having different altitudes. Accordingly, *Asspergillus* spp(84.74 %), *Fusarium*spp(8.75%), Penicillium spp(5.49%) and Rhizopus spp(1.02%) were recorded. The mean ochratoxin A (OTA) detected from different coffee samples were; 6.24µg/kg, 2.05µg/kg and 1.2µg/kg from coffee bean samples collected from soil surface, dry and wet processed samples, respectively.
Conclusions & Perspectives:
In the present study, it was observed that coffee is contaminated by various filamentous molds during postharvest phases. The highest contamination level of mycotoxigenic fungi were found among coffee samples collected from soil surface while lowest contamination was from wet processed coffee from soil and the lowest fungal incidence was observed in wet processed coffee beans. According to the results of the current study, those who are engaged in coffee production, processing, and transport should adhere to appropriate agricultural and manufacturing practices, and there should be regular assessment in order to take a correction measure.
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S6-O-02

Coffee pulp byproduct – stabilization and characterization for a potential economic boost as a source of carbohydrates

Passos Cláudia P.[1] (cpassos@ua.pt), Galrinho Miguel[1], Carriço Matilde[1], Petronilho Sílvia[1, 2], Alves Rita C.[3], Costa Anabela[3], Oliveira M. Beatriz P. P.[3], Ferreira Sónia S.[1], Coimbra Manuel A.[1]

[1] *LAQV/REQUIMTE, Department of Chemistry, University of Aveiro, Aveiro, Portugal* ; [2] *CQ-VR, Department of Chemistry, UTAD, Vila Real, Portugal* ; [3] *LAQV/REQUIMTE, Department of Chemical Sciences, Faculty of Pharmacy, University of Porto, Porto, Portugal*

Rationale:
During coffee processing, several byproducts are discarded [1], despite the presence of compounds of interest, including carbohydrates (free, oligosaccharides, and polysaccharides). Oligosaccharides, in particular, can contribute with prebiotic effect [2], potentially reducing the metabolic syndrome risk [3]. The characterization of coffee byproducts can thus define applications and provide additional sources of income for farmers. This work aimed to extract and characterize carbohydrates obtained from coffee pulps produced in Azores after applying different drying processes for stabilization.

Methods:
Mature coffee cherries were manually collected from *Coffea arabica* plants produced in Azores (Portugal). The fruits were washed with tap water, dried with blotting paper, and manually depulped. The pulps were then divided into 2 groups: 1) freeze-dried, and 2) oven-dried at 40°C. A 3rd sample was alternatively dried using a convection walk-in type dryer placed in the field. The samples were treated in a sequential procedure: 1) using cold water or ethanol (85%, v/v) at 80°C for 10 min, 2) hot water at 80°C for 2h. The remaining insoluble materials were also collected. All extracts were characterized for their neutral/uronic acids carbohydrate composition, including free, oligomeric, and reducing sugars content.

Results:
The Azores' pulps contained a total sugar content of 28-44%, most of which contributing to reducing sugars present in the dried pulp. Most of the free and oligomeric sugars were recovered in the ethanolic/cold water extracts while pectin-rich extracts were recovered with hot water. The remaining insoluble residues, which account for 32-52% of dried pulps, still contained 40-60% of carbohydrates and may represent an additional source of insoluble fibre. In all, the carbohydrate composition was much more dependent on the extraction solvent used, than on the drying process applied.

Conclusions:
Different drying approaches can be applied to stabilize coffee pulp, which is a sustainable source of soluble and insoluble fibre and, potentially, a source of oligosaccharides, that can be explored to improve conditions in the gut.

Acknowledgments: The authors acknowledge national funds from FCT/MCTES to project COBY4HEALTH (PTDC/SAU-NUT/2165/2021), research units LAQV-REQUIMTE (UIDB/50006/2020 and UIDP/50006/2020) and CQ-VR at UTAD Vila Real (UIDP/00616/2020), R.A. (CEECIND/01120/2017), C.P. (CEECIND/01873/2017) contracts, and S.P. through her post-doc grant (SFRH/BPD/117213/2016). S.F. acknowledges LAQV-REQUIMTE research contract. M.G. thanks COBY4HEALTH for MSc. Grant. The authors also thank the coffee producer Ricardo Cidade for the samples.

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S6-O-03

Oligosaccharides and Cyclitols derivatives in green *Coffea arabica* from different geographical origins

De Angelis Elisabetta[1] (elisabetta.deangelis@illy.com), Navarini Luciano[2]

[1] *Aromalab AREA Science Park, illycaffè spa, Trieste, Italy* ; [2] *illycaffè spa, Trieste, Italy*

Rationale:
Carbohydrates are the main chemical constituents of green coffee, and they account for 50% of its dry matter, on average [1]. Regarding low molecular weight carbohydrates, oligosaccharides are the major components being sucrose the most abundant (4-8%) followed by small amounts of raffinose and stachyose [2]. Regarding inositol derivatives, *myo*-inositol, bornesitol and D-pinitol have been detected in green coffee as well as in coffee substitutes [3-4]. As far as galactosyl cyclitols is concerned, galactinol is the only one found in green coffee [5]. In a previous preliminary investigation, an unknown compound was occasionally detected and tentatively identified as ciceritol by using a chickpea extract as a surrogate standard (in preparation). Unfortunately, quali- quantitative reported data on green Arabica oligosaccharides and cyclitols derivatives are still fragmentary and the present study is aimed at contributing to deepen the knowledge on these classes of constituents considering their role in revealing possible coffee adulteration and from a plant physiology point of view.

Methods:
Wet processed green coffee (*C. arabica* L.) commercial lot samples from 12 different geographical origins were used. Soluble sugars were extracted by using hot water (100°C). Sugars analysis was performed by HPLC system equipped with a Refractive Index detector with acetonitrile/Milli-Q water (60:40) as a mobile phase. Isocratic conditions by using a ZORBAX-Carbohydrate analytical column (5 µm, 4.6 mm x 250 mm) were used. The compounds were identified by using external commercial standard (not for ciceritol) and they were quantified by using single calibration curve for each standard.

Results:
Sucrose, *myo*-inositol and stachyose were systematically detected and quantified in every analyzed sample. No trend depending on geographical origin was observed. Raffinose was occasionally detected in trace amount. The presence of ciceritol (30 – 190 mg/100g DW) in some samples was confirmed. This cyclitol derivative was systematically detected in all analyzed samples from Ethiopia. No other oligosaccharides and cyclitols derivatives were detected.

Conclusions & Perspectives:
The present work, in addition to confirm the relevant role played by sucrose as prevailing oligosaccharide in green Arabica, as expected, put in evidence the systematic presence of *myo*-inositol and stachyose. Raffinose and ciceritol were occasionally detected. The latter seems to be a possible marker of Ethiopian green Arabica. This study, in addition to open new horizon from a plant physiology point of view, it may be helpful in both preventing and revealing possible coffee adulteration.

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S4-O-01

Comparative evaluation of effect of processing methods on coffee quality at Jimma, Ethiopia

Banti Misgana (misgana.banti@eiar.gov.et), Atlaw Tegene

Food Science and Nutrition Research Directorate, Ethiopian Institute of Agricultural Research, Addis Ababa, Oromia, Ethiopia

This study was designed to investigate the influence of coffee processing methods on coffee quality (raw, cup and biochemical composition) in Jimma, representing midland areas. Coffee samples were collected for Jimma agricultural research center, coffee breeding program research field and processed in three methods for the study. The result indicated that washed coffee beans scored the highest color (13.43) and odor (10) score than the other processing methods. The statistically best raw quality score (35.57%) was therefore reported for washed coffee in Jimma. Cup quality attributes however were not significantly affected by processing methods. Among chemical composition studied, lipid only was significantly affected by processing methods and highest lipid 13.74 and 13.17 g/100g was reported for semi-washed and washed coffee beans respectively. In general, as far as raw quality is considered, washed and semi washed coffee was found preferable in terms of coffee bean color and odor quality. However, despise the significant difference in some of the raw quality attributes, coffee beans with acceptable and to the standard quality can be produced by following any of the processing methods comparatively evaluated in this study. Further, investigation however is important in accessibility and economics of coffee processing methods in the area.

Keywords: Chemical compositions - Cup quality - Dry processed - Row quality - Semi-washed - Washed.

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ABSTRACTS THURSDAY 14 SEPTEMBER

ORAL PRESENTATIONS

SESSION 1:
Coffee plant science

S1-O-05

Leaf sugar metabolomic profiling reveals differences between *Coffea arabica* cultivars in two locations of Cerrado Mineiro (Brazil)

Campos Carréra Jéfyne[1, 2] (jefynecarrera@gmail.com), de Jesus Sartori Luana[3], Guerra-Guimarães Leonor[2, 4], Pinheiro Carla[5, 6], Silva Vânia Aparecida[7], Lordelo Volpato Margarete[7], Rodrigues Carvalho Gladyston[7], D'Auria John Charles[8], Mori Fabio Akira[9]

[1] *Departamento de Biologia, Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil* ; [2] *CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal* ; [3] *Departamento de Fitotecnia, Universidade Federal de Lavras, Lavras, Minas Gerais, Brazil* ; [4] *LEAF and Associated Laboratory TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Lisboa, Portugal* ; [5] *UCIBIO Applied Molecular Biosciences Unit, Department of Life Sciences, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [6] *Associate Laboratory i4HB Institute for Health and Bioeconomy, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [7] *EPAMIG – Empresa de Pesquisa Agropecuária de Minas Gerais, Lavras, Minas Gerais, Brazil* ; [8] *Research Group Metabolic Diversity, Department of Molecular Genetics, Leibniz Institute of Plant Genetics and Crop Plant Research (IPK Gatersleben), Gatersleben, Germany* ; [9] *Departamento de Ciências Florestais, Universidade Federal de Lavras, Lavras, Brazil*

Rationale:
Brazil is the largest arabica coffee exporter, Minas Gerais being the state responsible for more than 50% of the Brazilian coffee production. In Cerrado Mineiro (Minas Gerais), coffee plants are often irrigated due to drought conditions, which could compromise coffee production. Besides, during drought conditions, sugar allocation, metabolism, and transport in plants are significantly affected. The objective of the present study was to analyze the sugar metabolism of five *Coffea arabica* L. cultivars in two distinct experimental areas of Cerrado Mineiro, with different irrigation conditions.

Methods:
The study was conducted in two experimental locations, Monte Carmelo and Patrocínio, in Cerrado Mineiro region. Five *Coffea arabica* cultivars (Catuaí Vermelho IAC 144, Catiguá MG2, MGS Catiguá MG3, MGS Paraíso II, and Sarchimor MG 8840) were selected for their drought tolerance. Expanded leaves were collected early morning and evaluated for: starch accumulation by spectrophotometry, and untargeted metabolomic analysis by GC-TOF-MS (splitless mode). Annotation of the metabolites was based on GOLM and KEGG metabolites databases. The statistical tests and pathway analysis were carried out by R software and MetaboAnalyst 5.0.

Results:
Starch content analysis revealed differences between cultivars and experimental location. Plotting PLS-DA with metabolic features (GC-TOF-MS, splitless mode) showed a separation of Catiguá MG2 from the other cultivars at both experimental locations. Volcano plots of the sugar metabolites that change significantly in amount between Monte Carmelo and Patrocínio, also disclose Catiguá MG2 cultivar with the largest number of up-regulated features (19/20). Six pathways were significantly impacted, wherein starch and sucrose metabolism excelled over the others.

Conclusions & Perspectives:
The cultivars showed differences in their sugar metabolism in both experimental locations. Notably, Catiguá MG2 recognized for its relative tolerance to drought conditions, stood out from the others. Further studies are needed to evaluate the contribution of these metabolites in coffee's tolerance to drought. These findings could potentially hold valuable implications for coffee breeding programs.

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S1-O-06

Genome-wide association study identified SNPs and genes related to *Meloidogyne paranaensis* resistance in *Coffea arabica*

Silva Angelita[1, 2] (angelgarbossi@gmail.com), Ariyoshi Caroline[2, 3], Machado Andressa[4], Felicio Mariane[3], Shigueoka Luciana[5], Gustavo Sera[5], Pereira Luiz Filipe[2, 6]

[1] *Universidade Estadual de Londrina, Londrina, PR, Brazil* ; [2] *Plant Biotechnology Lab, Instituto de Desenvolvimento Rural do Paraná, Londrina, PR, Brazil* ; [3] *Instituto Nacional de Ciência e Tecnologia (INCT), Brasilia, DF, Brazil* ; [4] *Agronema-Análise, Consultoria e Experimentação Nematológicas, Londrina, PR, Brazil* ; [5] *Plant Breeding, Instituto de Desenvolvimento Rural do Paraná, Londrina, PR, Brazil* ; [6] *Embrapa Café, Brasilia, DF, Brazil*

Rationale:
Meloidogyne paranaensis is one of the most aggressive nematodes for coffee plants in Brazil. Using resistant cultivars stands as the foremost sustainable solution for farmers, however, the majority of *Coffea arabica* cultivars are susceptible to *M. paranaensis*. Meanwhile, *C. arabica* accessions coming from the historical FAO collection from Ethiopia have a valuable source of resistance to this nematode. Therefore, a Genome-Wide Association Study **(**GWAS) for *C. arabica* interaction with *M. paranaensis* was performed to identify SNPs and candidate genes associated with resistance to this nematode.

Methods:
Genotyping by Sequencing (GBS) of a collection of 159 wild accessions, mostly from FAO collection (FAO 1964) was used. Alignment was performed to the reference genome of *C. arabica* Et039 (SALOJÄRVI, 2021), to identify the SNPs. For each genotype, phenotyping was performed in 8 to 12 plants at greenhouse, inoculated with *M. paranaensis* (eggs and J1 stage). The interaction with nematodes was evaluated using the reproduction factor (RF), nematode per gram of root (NGR) and host susceptibility index (HSI). Genotypic and phenotypic data were associated using multi-locus models with the mrMLM (ZANG et al., 2020) and GAPIT3 (WANG et al., 2021) packages in R software.

Results:
Of the 124 genotypes inoculated with *M. paranaensis,* 25 showed FR<1. Meanwhile, the HSI analysis classified 80 genotypes as resistant. GWAS was performed with 11477 SNPs and detected 16 SNPs in at least two different association models and phenotyping analyses. In linkage disequilibrium with these 5 SNPs, candidate genes related to plant defense response were found: 3 genes encode a protein serine-threonine kinase, one encodes a CC-NB-LRR protein and another gene encodes an endo-1β-glucan-glucan.

Conclusions & Perspectives:
Through GWAS it was possible to identify SNPs, genomic regions and genes involved in the interaction between *M. paranaensis*, and C. *arabica*. The SNPs are being validated using the Taqman®, for application in marker-assisted selection on coffee breeding programs. Also, the transcriptional response of the identified genes will be performed during the plant-pathogen interaction in order to understand the mechanism of coffee resistance response to *M. paranaensis*.

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The Innovea Global Coffee Breeding Network

Humphrey Tania[1] (tania@worldcoffeeresearch.org), Berny Mier y Teran Jorge[2], Kotch George[3], Muir Nick[4], Barrera Santos[5]

[1] *World Coffee Research, Portland, Oregon[OR], USA* ; [2] *World Coffee Research, Merida, Mexico* ; [3] *Consultant, Woodland, USA* ; [4] *World Coffee Research, San Jose, Costa Rica* ; [5] *World Coffee Research, Cali, Columbia*

Rationale:
The future of coffee agriculture depends on accelerating the development of better varieties. Given the timelines for breeding a tree crop like coffee and the reality of climate change, using modern breeding tools to speed up genetic gain and multi-environment testing is absolutely essential. Further, using principles of demand-led breeding ensures that finished varieties are ones farmers want to grow and that roasters and consumers want to buy.
World Coffee Research, together with nine international partners have recently launched Innovea, a collaborative global network of Arabica coffee breeders. This network will enable achievements that would not be possible for a more traditional breeding program operating within the borders of a single country.
Methods:
The network's primary focus is on population improvement through rapid cycling marker-assisted recurrent selection. These improved and diverse populations are distributed to network participants every 6 years. This replenishes national breeding programs with a continual supply of superior breeding material that can be used without any intellectual property restrictions. Participating countries can use the improved germplasm to cross with their own material, as well as to develop and release their own finished varieties tailored for local conditions and niche market demand.
The network's breeding population is being created from a wide diversity of high-performing varieties from Africa, Asia, and the Americas. The crosses have been designed to bring together new combinations focused on yield, disease resistance, and cup quality. Phenotyping is carried out by partners at globally distributed sites across different agroecological environments, exposing them to diverse and sometimes extreme environmental pressures. Global performance data will be aggregated using genomic selection to centralize recombination at WCR's breeding factory in Costa Rica. Each new population cycle will recombine individuals with the highest breeding values across traits and allow opportunity to introduce new genetic diversity.
Results:
Nine countries have signed on as partners of this network which is funded by more than 200 member companies from 27 countries that make up World Coffee Research. The first breeding cycle has been initiated with crosses performed in El Salvador, Costa Rica and Rwanda and seed distributed to network partners.
Conclusions & Perspectives:
The globally coordinated network has brought together diverse genetic material and is building a wide breeding pipeline that provides tremendous value to countries unable to tackle the challenges of climate change on their own.

S1-O-08

Genetic diversity of *Coffea arabica*: significant update for its conservation and optimal use for breeding

Benti Tadesse[1] (tadessebenti@gmail.com), Christophe Montagnon[2], Faris Sheibbani[3], Debela Adugna[4]

[1] *Ethiopian Institute of Agricultural Research (EIAR), Jimma, Oromiya, Ethiopia* ; [2] *RD2 vision, Montpellier, France* ; [3] *Qima coffee, Fitzrovia, United Kingdom* ; [4] *Ethiopian Coffee and Tea Authority, Addis Ababa, Ethiopia*

Rationale:
The genetic diversity of *C. arabica* is acknowledged to be very low. Recent studies significantly increased our knowledge of the structure of the genetic diversity to optimize its conservation and use in a climate change context.
Methods:
Recent scientific articles regarding the genetic diversity of *C. arabica* [1-4] are reviewed. These articles include a wide range of samples covering South Sudan, Ethiopia and Yemen, as well as major cultivated varieties around the world. It gives a unique insight and a global comprehension of *C. arabica* genetic diversity and early domestication movements is suggested.
Results:
It has been confirmed that South Sudan is a native habitat for *C. arabica* trees and proven that they are genetically different from their Ethiopian counterparts. The South-East of the Rift Valley is the origin of the seeds that led to domestication through the Ethiopian Legacy genetic group that further gave rise to Typica/Bourbon, New-Yemen and Harrar genetic groups. The last two groups are not found outside Yemen and Harrargue (Ethiopia) respectively.
Conclusions & Perspectives:
Only a small fraction of the low genetic diversity of *C. arabica* has been used for cultivation and breeding. Namely, South Sudan has not been significantly used while New Yemen and Harrar are not found outside their region of origin. It is urgent to preserve the newly identified genetic diversity of *C. arabica* and optimize breeding programs, namely the possible use of new combination of heterotic groups.

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Heterosis in F1 Arabica hybrids and its use under different agronomic conditions

Bertrand Benoît (bgbertrand3459@gmail.com)

DIADE/COFFEEADAPT/BIOS, CIRAD, Matagalpa, Nicaragua

Rationale:
Heterosis is defined as the superiority of the hybrid over the best of its parents. This phenomenon affects especially complex traits such as biomass and seed yield. F1 hybrid cultivars of Arabica coffee have been developed in Latin America by crossing dwarf pure lines 'American varieties' (A.V) x tall 'Ethiopian accessions (E.A)' or A.V x A.V. We have more than 30 years of hindsight on these varieties. How do F1 hybrids behave as a function of altitude (i.e. average temperatures), light intensity, and low-input conditions? Does this type of variety have a future to face the climate change?
Methods:
We present the main results of articles published between 2005 and 2022 from research started from 1991, where F1 are compared to A.V. Evaluations have been carried out by comparing F1 with the two parents in experimental trials or comparing F1 with A.V (G x E networks), in different altitudes, light intensity, and input conditions.
Main Results:
Basis of heterosis in Arabica: In experimental trials, E.A crossed by A.V produced high yielding F1 hybrids. F1 hybrids produced 75–80% more than A.V and 40–50% more than E.A, suggesting two heterotic groups. We did not observed heterosis between A.V x A.V.
Heterosis varies according to the characters : F1 hybrids produced a larger number of internodes over the same time lapse. The rust tolerance of susceptible F1 is superior to the rust tolerance of parents. Other characters of interest (i.e. seed size, sensory quality) are not altered by heterosis. For seed size and shape we suspect a maternal inheritance.
Heterosis & G x E: Heterosis is higher at low and medium altitudes (i.e.T°) and are stronger in sub-optimal conditions. There are no clear conclusions about light intensity. F1 Hybrids are more stable over environments than A.V for biomass and yield traits.
Conclusions:
The performance of the F1 are far beyond exceed the productivity of the best A.V. The absence of heterosis in AVxAV is probably due to the very small genetic distance between the A.V. Homeostasis appears as an important and essential component of heterosis in Arabica F1.
F1 hybrids always appear superior to A.V in low/medium altitude and in low/high-input or sun/shade conditions. Finding heterosis in an allopolyploid, autogamous and as low polymorphic species as Arabica is a great opportunity to increase the productivity and address the challenge of climate change. Farmers adopt the F1 varieties because they offer higher yields and fewer risks than other coffee varieties. However, the production cost of a hybrid seed is a major deterrent. The control of male sterility is a strategic element of any Arabica breeding program focused on F1 hybrids.

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Heterosis Breeding: A prospective strategy for Arabica coffee improvement in India

Das Divya Kallingapuram[1] (divyudas@gmail.com), Manjunatha Byadarahalli Nagraraju[1], Devasia Jeena[1], Sureshkumar Vettiyoor Brammayagowder[1], Shivanna Manchanahally Byrappa[2], Surya Prakash Nayani[1]

[1] *Plant Breeding and Genetics, Central Coffee Research Institute, Chikkamagaluru, Karnataka, India* ; [2] *Applied Botany, Kuvempu University, Shimogha, Karnataka, India*

Coffee being a perennial crop, developing varieties through conventional breeding is a long-term process and it takes a couple of decades to develop, evaluate and release a true breeding variety. Therefore, heterosis breeding strategy for development of elite F_1 hybrids of Arabica is gaining high significance. Besides reducing the time frame for varietal development, this strategy enables the exploitation of heterosis and also gains an advantage from the expression of resistance genes of dominant nature in F_1 progenies. In this context, the development of F_1 hybrids of Arabica coffee has been undertaken in India to evolve heterotic F_1 hybrids of Arabica for yield coupled with durable resistance to coffee leaf rust (CLR) disease.

Methods:

A total of 18 F_1 hybrids (S.5052, S.5053, S.5057, S.5058, S.5059, S.5079 to S.5080, S.5081 &S.5082, S.5083 to S.5086, S.5087 to S.5090 & S.5093) of Arabica formed the material for the present study. With the objective of pyramiding of S_H3 gene of *C. liberica* origin that governs rust resistance into various semi-dwarf genotypes, Sln.10, a double cross hybrid derivative of Arabica that possess S_H3 gene for rust resistance, was consciously used as one of the donor parent. Field performance of the F_1 hybrids in respect of vegetative vigour, yield component characters, yield, bean and beverage quality as well as field tolerance to coffee leaf rust was evaluated under traditional shade grown conditions.

Results:

Among the 18 crosses evaluated, three F_1 hybrid lines (S.5059, S.5085 & S.5086) were identified to be promising with a cumulative mean yield ranging from 1500 - 1700 kg cc/ha. The percent of relative heterosis in shortlisted hybrids ranged from 20.72 to 37.5 while the heterobeltiosis ranged from 10.26 to 24.24% in low and high cropping years respectively. The bean size as indicated by total 'A' grade beans ranged from 66.27 to 70% among the hybrids. The hybrids, S.5085 and S.5086 were totally free from CLR incidence and the cupping scores (SCAA score) ranged between 73 and 81. The integration of S_H3 gene in hybrid progenies has been tracked through SCAR marker assays.

Conclusions & Perspectives:

The study highlighted the promising performance of F_1hybrids as reflected in terms of relative heterosis and heterobeltiosis and also validated the suitability of heterosis breeding strategy for yield improvement in arabica. Further, the pyramiding of S_H3 could be successfully achieved that contributed for manifestation of high field tolerance to CLR in the F_1 hybrids. In conclusion, the study provided useful insights in commercial prospects of heterosis breeding in coffee by adopting an appropriate multiplication strategy.

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S1-O-11

The Democratic Republic of the Congo, the cradle of cultivated Robusta coffee (*Coffea canephora*), can we safeguard its coffee genetic resources of world importance?

Stoffelen Piet[1] (piet.Stoffelen@plantentuinmeise.be), Léonard Guillaume[2], Ithe Mwanga Mwanga Jean-Claude[3], Hatangi Yves[4], Kambale Bienfait[5], Asimoniyo Anio Justin[5], Tshimi David[6], Tas An-Sofie[1, 7], Depecker Jonas[1, 7, 7], Bollen Robrecht[1, 7], Poncet Valérie[8], Labouisse Jean-Pierre[9], Vi Tram[10], Assumani Angbonda Dieu-Merci[6], Vandelook Filip[1]

[1] *Meise Botanic Garden, Meise, Belgium* ; [2] *State Archives, Brussels, Belgium* ; [3] *IRSN, Lwiro, Democratic Republic of the Congo* ; [4] *Université de Kisangani, Kisangani, Democratic Republic of the Congo* ; [5] *Centre de Surveillance de la Biodiversité, Kisangani, Democratic Republic of the Congo* ; [6] *INERA, Yangambi, Democratic Republic of the Congo* ; [7] *K.U. Leuven, Leuven, Belgium* ; [8] *IRD, Montpellier, France* ; [9] *CIRAD, Montpellier, France* ; [10] *National Key Laboratory of Plant Cellular Biotechnology, Agricultural Genetics Institute, Hanoi, Vietnam*

Rationale:
Inventorying, conservation and evaluation of coffee genetic resources (CGR) in the DRC.
Methods:
Assesment of archives and of genetic, morphological and organoleptic characteristic of Robusta CGR.
Results:
Congolese Robusta CGR play a crucial role in the coffee production worldwide, but are poorly conserved.
Conclusions & Perspectives:
Important steps are made in order to study and conserve these important CGR, but they have to be accelerated considering the threats on these CGR.

Until the early of the 20th century *C. arabica* was the only coffee species of commercial significance, withstanding many attempts to introduce and cultivate other species such as *C. liberica s.l., C. congensis, C. stenophylla*and genetic lines of *C. canephora.* However, the discovery (late 19thcentury) and introduction (early 20th century) of "*Coffea robusta"* was a game changer. Although the name *C. robusta* is proven to be synonym with *C. canephora*, the commercial name, Robusta, was settled and is to this day a witness of the importance of this introduction based on Robusta CGR sourced from the Sankuru region in the DR Congo, which was principally distributed via the Java Coffee Research Station. Over one century, the share of Robusta is steadily growing from *quasi nihil* to today more than 40% of the coffee production.

Later breeding programs (1930-60) in the DR Congo (at the Lula and Yangambi Coffee Research Stations), Ivory Coast (1970-80's) and Vietnam (1980-90's) were intensively using Congolese CGR, as these have higher yields and better tolerance to coffee berry borer, rust and tracheomycosis, compared to *C. canephora* GR from other regions of its natural distribution. Today, Congolese CGR represents more than 75% of the genetic diversity of the cultivated Robusta of Côte d'Ivoire, Guinea and Vietnam. Accessions preserved in common gardens are either of pure Congolese origin or 1st generation or advanced Congolese hybrids. Additionally, ongoing evaluation of the INERA coffee collection in Yangambi is illustrating the organoleptic and agronomic potential of the cultivated and wild Congolese CGR.

Congolese CGR are under pressure due to deforestation, habitat degradation and climate change. In order to safeguard them for the future we need to invest in local infrastructure and enforce local capacities in conservation and research. An action plan for *ex-situ*and *in-situ* conservation is needed. Several steps have already been made with the support of the EU (11th EDF, FORETS Project, *FED/2016/381-145*), Belgium (Belspo-BRAIN, B2/191/P1/COFFEEBRIDGE) and the Flanders Environment (Climcoff-project), but many more steps are needed.

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ORAL PRESENTATIONS

SESSION M2:
Miscellaneous 2

M2-O-01

New methodology to calculate the caloric value of traditional *espresso* coffee: bridging the gap between legislation and coffee chemistry

Navarini Luciano[1] (luciano.navarini@illy.com), Tieppo Michele[2], Foschia Valentina[1], Perinello Giampaolo[2], Petracco Marino[1]

[1] *illycaffè spa, Trieste, Italy* ; [2] *Merieux Nutrisciences Italia, Resana (TV), Italy*

The caloric value of foods is traditionally taken by adding up the contributions of proteins, fats and carbohydrates, each with a conversion factor into energy. The analytical methods are well established and explicitly mentioned in the legislation - i.e. the Kjeldahl nitrogen for protein. However, at least as far as coffee is concerned, this recommendation is chemically challenging, because proteins are thermally degraded and mostly converted into Maillard end products known as melanoidins, whose degree of digestibility and bioavailability in organisms is generally poor [1]. Moreover, the first Kjeldahl crude «protein» has to be corrected for other nitrogen sources like caffeine and trigonelline which are well known and quite abundant coffee compounds. In the case of *espresso* coffee, the lipids present in R&G coffee are stripped thanks to the applied pressure during the beverage preparation. However, in view of the short percolation time used in *espresso*brewing, only trace contents of lipids (around 50-100 mg/cup) in the brew can be found. For carbohydrate determination, in former times the method of choice very often was a calculation, adding up all other components to 100 %. Also in this case, the practice is not in compliance with coffee chemistry. In fact, glucose, fructose, sucrose, and sugar alcohols, certainly digestible carbohydrates, are found in extremely small quantities in the coffee extract, due to their fate after roasting in generating volatile organic compounds. In the present study, *espresso* coffee brews (100% C. arabica) prepared according to well defined conditions have been analyzed according to two different analytical methods: the method according to [2] and a new method *ad hoc*developed to consider the chemical specificity of the coffee matrix. Their caloric value has been subsequently calculated.

Traditional *espresso*coffee brews (regular and decaffeinated) have been prepared under well-defined conditions [3] by using Marzocco Linea 2 AV coffee machine. Proteins according to both Kjeldhal (N x 6.25) and as a sum of post-hydrolyis aminoacids, fibers high MW and carbohydrates by both difference to 100 and as a sum of sugars have been determined.

According to the standard method (and approximation) a regular 20 mL *espresso* contain 5 kcal whereas according to the new method, 2 kcal only. Similar profile has been obtained for a decaf 20 mL *espresso*. The caloric value of traditional *espresso* coffee was found to be remarkably affected by the method chosen, suggesting that the analytical procedures should be better adapted to the product of interest and cannot be used without taking into the account product preparation and chemistry.

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M2-O-02

Flavor Components of Coffee Beans Analyzed by headspace solid-phase microextraction / gas chromatography-mass spectrometry and Electronic Sensor Techniques

Chen Zhenjia[1] (905088983@qq.com), Liang Jingsi[2], Zhang Xiaomei[3], Du Ping[4]

[1] *coffee sciences, coffee engineering research center of China, Mangs, China, PR China* ; [2] *Coffee Science, coffee engineering research center of China, Mang City, Dehong, PR China* ; [3] *Agriculture and Biology, Dehong Teacher's College, Mang City, Dehong, PR China* ; [4] *Analytic & Testing Research Center of Yunnan, Kunming University of Science and Technology, Kunming, PR China*

The paper reports the differences of volatile components and sensory substances in different varieties. The volatile components, aroma and taste of 9 roasted coffee beans were analyzed by HS-SPME-GC-MS, electronic nose (E-nose) and E-tongue techniques. The HS-SPME-GC-MS results showed that basically the volatile components of different varieties beans were similar. Forty-five volatile components were determined by searching spectrum library and following retention index. The furfural, 3-furan methanol, 5-methylfuranal were present at high concentrations at 15.6, 12.1 and 9.9% respectively. The PCA and cluster analysis revealed the differential characteristics of coffee varieties. The test results of the E-nose showed that the coffee aroma fingerprints were similar. The analysis data of E-tongue combined with discriminant function analysis showed that the nine varieties of coffee roasted beans had their own unique taste. HS-SPME-GC-MS combined with E-sensory analysis technology can distinguish different varieties and provide a scientific theoretical basis for the flavor traceability information of coffee varieties (Fig. 1).

Keywords: HS-SPME-GC-MS - E-nose - E-tongue - Flavor components.

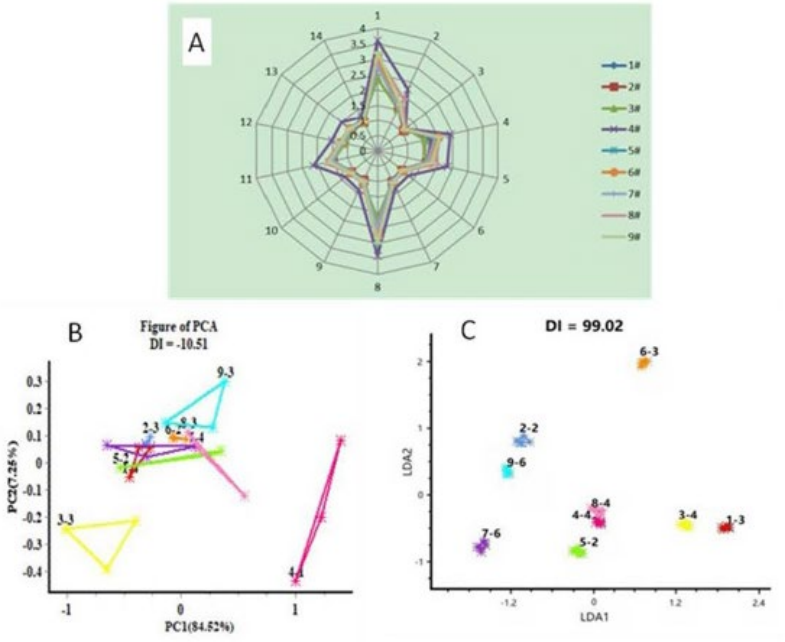

Fig. 1 - Electronic sensor technique analyzed results.
A and B: radar chart and PCA plot by E-nose response, respectively; C: LDA plot by E-tongue.

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M2-O-03

Influence of fuel types on roasting results and sustainability

Koziorowski Thomas (t.koziorowski@probat.com), Wißen Dietmar, Damen Michael, Bongers Sandra

R&D, Probat AG, Emmerich am Rhein, Germany

Rationale:
With the need for more sustainability roasting processes and in link with the future availability of fuels for roasting the question is if there are alternatives available. And if yes what would be the influence on sustainability, the roasting process, flavour and taste results.
Methods:
A study was done to evaluate alternatives. Based on this, hydrogen, biogas and electrical heating were selected as focal points for a proof of concept.
In this context, the questions
- Influence on the roasting behaviour?
- Can the same roasting results be achieved, especially with regard to taste?
- Which procedural adjustments would be necessary for this?
- Change in the emissions of the roasting process due to the selected fuels?
- Impact on the carbon footprint of the roasting process?

are backed with working theses and these theses are then checked by experimental tests and measurements. To check the selected theses, a roaster type with a batch size of 5 kg was designed with three different types of heating systems: natural gas, hydrogen and electrical heating.
Results:
The necessary adjustments to the heating systems could be determined and implemented. With optimal control systems, the same roasting curves can be mapped, which can also be transferred between the systems. Comparable energy consumption was also measured. With the help of an e-tongue taste sensor, which is a biomimetic technology, and triangle cuppings, the roasting results could be compared, and it could be shown that the same taste results can be achieved. Depending on the type of fuel, emissions can be reduced by up to 15%. At the same time, the carbon footprint was reduced by 90%.
Conclusions & Perspectives:
It was shown that alternative and sustainable forms of energy can be used to roast coffee. At the same time, the carbon footprint of the roasting process is significantly reduced. In a next step, this must now also be considered for industrial roasters with their recirculating air systems.

M2-O-04

Zero Discharge Water Treatment at Coffee Wet Mill

Sara Carl[1] (carl.sara@sucafina.com), Perotti Ermanno[2]

[1] *Sucafina, Kunming, China* ; [2] *Upstream and Global Origins Innovation, Sucafina, Ho Chi Minh, Rieti, Vietnam*

Rationale:
Coffee wet mills face many sustainability challenges: water health, decarbonisation, energy efficiency, quality management, operational efficiency, and Government Regulations. Existing solutions for some of these challenges are often counter to other concerns: E.g., using less water can negatively impact quality, inefficient heat/energy increases carbon footprint, and so on. Furthermore, current research does not provide evidence required to enable improvement through existing water treatment strategies. This is why we have developed a Zero Water Discharge system, designed to holistically address the myriad of challenges mentioned above while also reducing the amount of water needed during processing and cleaning it to a point where it can be recycled with only loss by evaporation.

Methods:
The Zero Discharge system we have designed yields two outputs from the wet-milling process: clean and reusable water and mud that can be added to fields or combined with fuel and burned. It processes a minimum of 30MT of dirty water, which is collected into a tank. Flocculants and a self-cleaning mechanical filter remove suspended solids, and then a Fenton Reaction using hydrogen peroxide and ferrous iron further removes contaminants. The cleaner water is put into an evaporation chamber under pressure. Once condensed, the water passes through a reverse osmosis system and is pumped back to the top storage for re-use. Evaporation byproducts are further processed with flocculants and Fenton Reaction, and a filter then rejoins the repass system. A high-efficiency biomass steam boiler and solar water heaters are used for all energy used in cleaning and drying coffee. Upon request, an additional filter can be added to make the clean water potable.

Results:
Even from the worst possible inputs, the water treatment output levels we have generated all comply with requirements and international environmental standards, proving that the system works. From an operational and energy viewpoint, the system is extremely efficient, is able to run one full cycle in 24 hours, requires little labor and only uses 24-40% of traditional biomass fuel. The footprint is minimal, the system is small, and it requires no ponds.

Conclusions & Perspectives:
The system represents significant innovation for the coffee industry, solving many issues faced. In addition, a smaller and transportable design (with readily available inputs housed in a pre-built sled-in-container system that can be used globally) is now in development and will soon be available.

M2-O-05

Species and Geographical Origin Authentication of Philippine Coffee using XRF-based Multi-element and Stable Isotope Ratio Profiling Combined with Chemometric tools

Tan Kevin Neil[1] (kevin_neil_tan@dlsu.edu.ph), Garcia Emmanuel[2], Rallos Roland[3], Bautista VII Angel[4]

[1] *Chemistry Department, De La Salle University, Manila, Philippines* ; [2] *Chemistry Department/ La Salle Food and Water Institute, De La Salle University, Manila, Philippines* ; [3] *Agriculture Research Section, Philippine Nuclear Research Institute, Quezon City, Philippines* ; [4] *Nuclear Materials Research Section, Philippine Nuclear Research Institute, Quezon City, Philippines*

Rationale:
Multi-element and stable isotope ratio (SIR) profiling with chemometrics and machine learning techniques can provide a means to differentiate roasted coffee beans based on their species (Arabica and Robusta) and geographical origin. This approach can help mitigate food fraud and secure the geographical indication (GI) of Philippine coffee. Cultivation practices, post-harvest processes, and environmental factors such as soil composition, precipitation, temperature, and altitude influence the chemical composition of a coffee bean.

Methods:
A total of fifty-six (56) roasted coffee bean samples were collected from the participants of the 2022 Philippine Coffee Quality Competition. Eight (8) commercially available roasted coffee beans were also collected. XRF-based multi-element and stable isotope ratio profiles from these two sets of samples were subjected to principal component analysis (PCA), linear discriminant analysis (LDA), and random forest (RF). Samples are categorized based on regions. The quantities of P, S, K, Ca, Mn, Fe, Cu, Zn, Rb, Sr, $\delta^{13}C$, and $\delta^{15}N$ were utilized to differentiate samples based on species and geographical origin.

Results:
RF provides higher accuracy than LDA on species classification (100% vs. 98.65%). On the other hand, origin classification accuracy is higher in LDA than in RF (94.48% vs. 68.52%). Including SIRs ($\delta^{13}C$ and $\delta^{15}N$) as explanatory variables for classification increases the accuracy of the LDA model by 8.95% and the RF model by 1.85% in geographical origin classification. Based on the generated models, $\delta^{13}C$ performs better than $\delta^{15}N$ in discriminating coffee based on geographical origin.

Conclusions & Perspectives:
XRF-based multi-element profiling can be used for high-throughput screening of species and the geographical origin of coffee. XRF is a fast, cost-efficient, and reliable instrumental method for multi-elemental analysis. LDA and RF are viable statistical tools for utilizing XRF-based multi-element and SIR profiles to classify coffee accurately based on species and geographical origin.

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M2-O-06

Variability and association between biochimical constituents and organoleptic quality attributing traits in Ethiopian coffee (*Coffea arabica* L.) accessions

Weldemichael Getachew[1] (getachewweldemichael@gmail.com), Alamerew Sentayehu[2], Tulu Leta[3], Berecha Gezahegn[4]

[1] *Coffe and tea research program, EThiopian Institute of Agricultural Research, Jimma, Oromiya, Ethiopia* ; [2] *Crop research, Holeta agricultural research center, Holeta, Oromiya, Ethiopia* ; [3] *Plant biotechnology, NatiNational Agricultural Biotechnology Research Center (NABRC, Holeta, Oromiya, Ethiopia* ; [4] *Horticulture and plant science, Jimma university, Jimma, Oromiya, Ethiopia*

Rationale:
Variations in coffee bean biochemical constitutes among the accession are believed to be important to determine the organoleptic quality of coffee and selecting consumer-preferred varieties. However, accessions collected from east Wollega have not been studied for such variations. The study was, therefore, conducted to evaluate the level of variability in bean biochemical composition and to assess its correlation with cup quality attributes.
Methods:
Four standard checks and 101 coffee accessions collected from east Wollega of Ethiopia were used for the study. The experiment was conducted using an augmented design and data on bean biochemical constitutes and organoleptic characters were recorded. Statistical analysis was performed using SAS software to see the variability among the accessions. The diversity was further assessed through cluster, genetic divergence, and principal component analysis. Finally, correlations among biochemical constituents and quality attributes were determined.
Results:
The result showed significant differences ($P<0.05$) among the accessions for most of the biochemical attributes. Besides, clustering grouped the accessions into six distinct clusters and two solitaries indicating the existence of variability among the accessions. Genetic divergence analyses showed significant inter-cluster distance, implying that there is a chance to improve these biochemical compounds through hybridization. Furthermore, the correlations coefficient showed crude fat content showed a positive and significant correlation with almost all desirable quality traits indicating the possibility of using crude fat content as indirect selection criteria to improve the cup quality of coffee. The correlations between trigonelline and total chlorogenic acid, dry matter content, and caffeine, and that of caffeine and protein were positive and significant. However, the relationship between trigonelline or total chlorogenic acid and crude protein and between crude protein and crude fat or dry matter was negative and significant
Conclusions & Perspectives:
In general, the observed variability for bean biochemical compounds creates a great opportunity for selection and hybridization to improve the biochemical content and cup quality of east Wollega coffee. Besides, the association of some of these important biochemical compounds with quality attributes would also be important for the simultaneous improvement of the traits. However, the variability observed in this study should be further confirmed by conducting the experiment in different locations as well as using molecular techniques.

Keywords: Crude fat - Crude protein - Correlation - Diversity - Wollega.

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M2-O-07

Genetic Variation Among Coffee Berry Borer (CBB) Localities in Jamaica

Myrie Ameka[1] (ameka.myrie@ur.de), Errbii Mohammed[2], Schrader Lukas[2], Schultner Eva[1], Oettler Jan[1]

[1] *Zoology / Evolutionary Biology, Universität Regensburg, Regensburg, Germany* ; [2] *Molecular Evolution and Sociobiology Institute for Evolution and Biodiversity, Münster, Germany*

Rationale:
The Coffee Berry Borer (*Hypothenemus hampei*, Scolytinae, Curculionidae) has invaded all major coffee-producing areas in the world [1]. The CBB is a model organism for studying rapid adaptation as it is a highly successful tramp species. Females mate with their flightless brothers inside the coffee berry, before flying off to infest new berries [2], limiting gene flow.
Methods:
We sampled CBBs from different elevations (and classifications of coffee) across Jamaica. Using whole-genome sequencing of individual and pools of beetles, and a new genome assembly based on MinION technology, we compared genetic variation within and between localities of CBBs in Jamaica.
Results:
Overall, low genetic variation was found compared to a main-land population (Panama), suggesting that the CBBs in Jamaica stem from one major introduction event. After 44 years and over ~250 generations after the CBB was first recorded on the island, we find some degree of genetic differentiation between localities across Jamaica.
Conclusions & Perspectives :
This finding lays the basis for future studies of rapid adaptation of this important pest insect.

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ORAL PRESENTATIONS

SESSION 2:
Plant Pathology & Protection

S2-O-05

Integrative transcriptomic and metabolomic approaches to unravel the resistance profile of Kawisari coffee against *Hemileia vastatrix*

Guerra-Guimarães Leonor[1, 2] , Azevedo Herlander[3], Diniz Inês[1, 2], Carrera Jéfyne[4], A.F. Guedes Fernanda[3], Pinheiro Carla[5], Gil Azinheira Helena[1, 2], Humberto Castro Pedro[3], Loureiro Andreia[1, 2], Jesus Muñoz-Pajares Antonio[6], Pereira Ana Paula[1, 2], Sottomayor Mariana[3], Tavares Silvia[1, 2, 7], Várzea Vítor[1, 2], D'Auria John[8], Batista Dora[1, 2], Silva Maria do Céu[1, 2] (mariaceusilva@isa.ulisboa.pt)

[1] *CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia (ISA), Universidade de Lisboa, Oeiras, Portugal*; [2] *LEAF-Linking Landscape, Environment, Agriculture and Food Research Center, Associate Laboratory TERRA, ISA, Universidade de Lisboa, Lisbon, Portugal* ; [3] *Centro de Investigação em Biodiversidade e Recursos Genéticos, Universidade do Porto, Porto, Portugal*; [4] *Departamento de Biologia, Universidade Federal de Lavras, Lavras, Brazil*; [5] *Department of Life Sciences, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Costa da Caparica, Portugal*; [6] *Departamento de Genética, Universidad de Granada, Granada, Spain*; [7] *Department of Plant and Environmental Sciences, University of Copenhagen, Copenhagen, Denmark* ; [8] *Department of Molecular Genetics, Leibniz Institute of Plant Genetics and Crop Plant Research, Leibniz, Germany*

Rationale:
Most of coffee commercial varieties are highly susceptible to *Hemileia vastatrix*, the causal agent of coffee leaf rust. The increasing societal expectations for sustainable coffee production demand the replacement of fungicide treatments with alternative strategies of plant protection, such as the use of coffee-resistant varieties without yield and quality losses. This work aims to unveil metabolite and transcriptional key signatures of coffee resistance by integrated omic´s data analysis.

Methods:
Leaves of Kawisari hybrid coffee (*Coffea arabica* × *C. liberica*) were inoculated with urediniospores of *H. vastatrix* race II and race XIII to establish an incompatible (Resistance - R) and compatible (Susceptibility - S) interaction, respectively. Leaves were collected at 1, 4, and 7 days after infection for: cytological evaluation of fungal growth and host responses; transcriptome analysis (RNA-seq); and untargeted metabolic analysis (GC-TOF-MS). Integrative analysis of transcriptomics/metabolomics data at the pathway level was performed using the MetaboAnalyst5.0 platform.

Results:
The post-haustorial resistance of Kawisari was associated with callose deposition around haustoria, hypersensitive response, and accumulation of phenolic-like compounds in host cells. A significantly higher percentage of infection sites with host responses were observed in resistance than in susceptible. When comparing resistant vs susceptible (R/S) transcriptomes and metabolomes, the expression of 127 genes and the amount of 117 metabolites change significantly in all time points. MetaboAnalyst integrative analysis unveiled 5 pathways that were significantly impacted: Photosynthetic carbon fixation; Pentose phosphate pathway; Glyoxylate and dicarboxylate metabolism; Phenylpropanoid biosynthesis; Glycine, serine, and threonine metabolism. The results highlighted the modulation of carbon and secondary metabolism as a response to *H. vastatrix* infection.

Conclusions & Perspectives:
Similarly, to our previous proteomic approach, carbon metabolism and stress/defence pathways were associated with coffee resistance. The integration of multi-omics data can provide systems-level insights, opening new perspectives for coffee breeding programs.

S2-O-06

Diversity and Antagonistic Potential of Mycoparasites on Coffee Leaf Rust *Hemileia vastatrix* in Ethiopia

Bekele Kifle Belachew (kiflekef@gmail.com)

Plant Protection Department of Coffee Pathology Section, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia

Rationale:
Coffee leaf rust (CLR), caused by *Hemileia vastatrix*, is the major diseas, occurring in the main coffee-growing countries. CLR management has relied on breeding for resistance and fungicides. Resistant variety development couldn't last long due to resistant breakdown. Fungicide use is costly and could compromise the final product market value. The failures of predominant management methods have led to the search for novel approaches and to the exploration of new alternatives. The study is of strategic importance, for proper collection, isolation and characterization of mycoparasites on *H. vastatrix,* in order to progress in biological control of CLR with antagonistic fungi. Therefore, the study was conducted to characterize the indigenous mycoparasites and to test antagonistic potential for the disease.

Methods:
In order to obtain potential biocontrol agents for the pathogen of CLR, a survey of fungicolous fungi associated with coffee leaf rust was conducted at major coffee producing areas of Ethiopia. The isolates characterization was conducted using the association of morphological, cultural and multigenic phylogenetic analysis using four genomic regions (LSU, ITS, TEF and RPB2). Moreover, the antagonistic potential the bioagents against CLR were conducted using gnrmination inhibition and leaf disc inoculation methods.

Results:
The results obtained from the survey showed very high diversity of mycoparasites. In total, 110 isolates were obtained from *H. vastatrix* pustule collections. From these ninety-nine mycoparasites were identified and categorized at genus level. The identified isolates belonging to therteen genera namely; *Akanthomyces, Alternaria, Cladosporium, Digitopodium, Fusarium, Gonatophragmium, Lecanicillium, Ochroconis, Paraphaeosphaeria, Phoma, Pleurodesmospora, Sarcopodium* and *Simplicillium.* From tested mycoparasites the highest germination inhibition and efficacy present on coffee leaf discs were recorded from *Digitopodium, Lecanicillium, Phoma, Fusarium, Cladosporium* and *Simplicillium* isolates.

Conclusions & Perspectives:
Biological control of CLR with mycoparasites remains promising possibility for the management of the CLR disease. Although little is known about mycoparasites of CLR, they may prove to be a valuable resource deserving more attention by mycologists, plant pathologists and biocontrol scientists.

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S2-O-07

Coffee berry disease: a century old anthracnose of green berries of Arabica coffee (*Coffea arabica* L.) in Africa

Adugna Girma (girma.adugna@ju.edu.et)

Horticulture and Plant Sciences, Jimma University, Jimma, Ethiopia

Coffee Berry Disease (CBD), anthracnose of green berries of Arabica coffee, chronicles 100 years in 2022. The disease was detected for the first time in Kenya by J. McDonald at the end of 1922. He described CBD symptoms and attributed its causal pathogen to *Colletotrichum coffeanum* Noack (renamed *C. kahawae*). CBD has been causing substantial yield losses (ca. 80%) in countries without disease management strategies. There has been no coffee disease with a remarkable economic impact as CBD, dwindling Africa's share of world coffee production from 27% in the 1970s to 13% in the 2000s and resulting in sharp falling of total Arabica coffee exports over the last three decades. A considerable amount of scientific knowledge has been documented on the fungus biology, epidemiology and management of Coffee Berry Disease during the past 100 years. The use of resistant varieties is the most empirical and effective CBDmanagement practices in East Africa. The disease is still of great concern to Arabica producers and exporters worldwide. There are several unresolved issues demanding due attentions of scientists and coffee communities. The fungus taxonomic position has been confusing pathologists in identifying the actual cause of anthracnose on coffee berries and other hosts because of several nomenclatures (*C. coffeanum*, *C. kahawae*, *C. kahawae* subsp. *kahawae* and *C. kahawae* subsp. *cigarro*). The host resistance is long-lasting as no change in reactions of released coffee varieties in Ethiopia and Kenya for the past 40 to 45 years. However, the nature of resistance and its inheritance mechanisms remained as a major point of debate (polygenic vs. oligogenic resistance) implicating that genetics of CBD resistance needs further in depth analysis of host-pathogen interactions using contemporary molecular technologies. Thorough understanding of the pathogenicity (aggressiveness/virulence) and host defense (preformed and induced) systems employing cellular, genomic and metabolic traits in the interplay of both organisms in ambient settings. The interaction protocols should be primarily optimized and standardized on known susceptible, intermediate and resistant coffee varieties (pure and introgressed lines) including inoculation and quantifying (scales 5 or 12 classes) reactions of host organs (hypocotyls and berries). This comprehensive review gives detail insights of published results in journals, proceedings and dissertations during the past 100 years that demonstrate success stories; pinpoint contrasting research gaps that motivate scientists and sensitize coffee communities on the impact of Coffee Berry Disease in Africa and beyond.

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S2-O-08

Field performance of Arabica coffee genotypes for growth traits, yield, bean quality and disease tolerance

Aluka Pauline[1] (p.aluka2012@gmail.com), Musoli Pascal[1], Kyaligonza Vincent[1], Kobusinge Judith[2], Mulindwa Joseph[3], Kagezi Godfrey[2], Sseremba Godfrey[1], Arinaitwe Geofrey[4], Owere Lawrence[5]

[1] *Coffee Cocoa Variety Improvement and Management, National Coffee Cocoa Research Institute (NaCORI), Mukono, NA, Uganda*; [2] *Coffee Cocoa Plant health management, National Coffee Cocoa Research Institute (NaCORI), Mukono, NA, Uganda* ; [3] *Coffee Cocoa Value Addition, National Coffee Cocoa Research Institute (NaCORI), Mukono, NA, Uganda* ; [4] *Director of Research, NaCORI, National Coffee Cocoa Research Institute (NaCORI), Mukono, NA, Uganda* ; [5] *Director of Research, BugiZARDI, Buginyanya Zonal Agricultural Research and Development Institute (BugiZARDI)), Mbale, NA, Uganda*

Rationale:
The proportionate contribution of Arabica coffee to Uganda's coffee production and export is only 20%, owing partially to inferior varieties. This study presents performance of 17 Ugandan Arabica coffee hybrid clones evaluated under different agro-ecologies to identify varieties with superior yields, bean quality, tolerance to coffee berry disease-CBD, coffee leaf rust-CLR, red blister disease, and key insect pests to minimise production costs, chemical use while increasing national and farmer income.[1]

Methods:
The 17 clones were selected from 165 FI hybrid trees. One Columbian variety (Castro), one variety from Kenya (Batian1) and one local commercial variety SL14 were included in the evaluation as controls. In year 2014, trials were planted at Bugusege (1450masl) and BugiZARDI (1900masl) as on-station sites, Zeu (1800 masl) in Zombo district and Dr Ruhemurama's farm (1760 masl) in Rukiga district. A Randomized Complete Block Design (RCBD) was used at a density of 1736 trees per hectare. Traits assessed included tree height, canopy diameter, yield, coffee bean size, weights, organoleptic cup taste, tolerance to CLR, CBD, red blister disease, major insect pests such as Antestia bugs, coffee berry borers, root mealybugs, stem borers, scales. Assessed traits constrain Arabica coffee production in Uganda.[2]

Results:
The 17 hybrid clones, Castro and Batian were significantly tolerant (p=0.05%) to CBD, CLR and red blister across sites. CBD and CLR cause national annual loss of US$ 100 million. SL14 was susceptible to CBD and CLR but not red blister. Genotype variation in pest incidence and severity was not statistically significant. Test genotypes had as good cup score and green bean size of over 80% as control SL14. The test clones were significantly shorter (p=0.05%) or as tall as controls. Yields of test genotypes, Castro and Batian ranged from 1278kg green coffee bean to 2962kg per hactare. SL14 had the least yield (929kg green beans per hactare).

Conclusions & Perspectives:
Genotype code D/11/6, D/12/12, D/11/7, A/3/13, A/4/13 yielded 0.5-39% higher than the best control which was Batian. D/11/6, D/12/12 and A/3/13 with respective green bean yields of 2959kg, 2909, 2217 and distinct characteristic green, bronze and gold young shoot colour identified for variety release and commercialization to boost farmer and national coffee production, productivity and use in Arabica coffee improvement.

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S2-O-09

First report of a genome sequence resource of *Colletotrichum kahawae*, the causal agent of coffee berry disease

Cabral Ana[1,2] (anacgpcabral@edu.ulisboa.pt), Carvalho Jessica[1], Talhinhas Pedro[1,2], Baroncelli Riccardo[3,4], Shittu Taiwo[5], Loureiro Andreia[2,6], Várzea Vitor[2,6], Diniz Inês[2,6], Batista Dora[2,6], Sreenivasaprasad S.[5], Silva Maria do Céu[2,6], Azinheira Helena[2,6]

[1] *Instituto Superior de Agronomia (ISA), Universidade de Lisboa, Lisbon, Portugal*; [2] *LEAF - Linking Landscape, Environment, Agriculture and Food Reseenter,Lisbon Associate Laboatory Terra, ISA, Universidade de Lisboa e Salamanca,Institute for Agrobiotechnology Research (CIALE), Universidad de Salamanca, Salamancdi Bologna, Dipartimento di Scienze e Tecnologie Agro-Alimentari, Università di Bologna, Bologna, Italy* ; [5] *Division of Science, Faculty Creative Arts, Techn. Sci. University Bedfordshire, Institute of Research in Applied Natural Sciences, Bedfordshire, United Kingdom*; [6] *CIFC-Centro de Investigação das Ferrugens do Cde Agronomia, Universidade de Lisboa, Oeiras, Portugal*

Rationale:
Coffee Berry disease is one of the most important diseases of Arabica coffee plants in Africa, which is caused by *Colletotrichum kahawae* a fungus from the Sordariomycetes class. *C. kahawae* is a specialized hemibiotrophic pathogen of green coffee berries, whose impact is especially important at high altitudes, where it causes yield losses of up to 80% if control measures are not undertaken. In the present work, the *C. kahawae* type strain CIFC_Que2 from Kenya was used for whole genome sequencing based on the Illumina sequencing platform aiming to generate a genome resource for understanding the pathogenicity mechanisms underlying the ability to infect green coffee berries and disclosing the underlying evolutionary events.

Methods:
Genomic DNA of the *C. kahawae* isolate CIFC_Que2 was obtained from mycethroughusing the DNeasy Plant DNA it (Qiagen), and used for Illumina sequencing. The reads were assembled into scaffolds. Gene predictions were performed, making use of the transcriptome information previously obtained. A batch of software tools was used to predict gene functions such as protein domains, putative secondary metabolite genes, candidate transcription factors, and secretome prediction.

Results:
The nuclear genome of *C. kahawae* was assembled into 886 contigs with 59,142,311 bp with a 98.9 % of completeness according to BUSCO. A total of 19181 protein-coding genes were predicted. The proteome was annotated using multiple public databases. Among the annotated protein-coding genes, 1774 were predicted as secreted proteins, of which 1549 were in the secretome and 358 were predicted as putative effectors. *In silico* analysis of the *C. kahawae* proteome allowed the identification of 869 proteases, a total of 967 carbohydrate active enzyme families, and the existence of 58 clusters of genes associated with secondary metabolites and 67 backbone enzymes. Further, transcriptomic studies showed that cutinases are essentially involved at the beginning of the infection, probably resulting in the penetration of the host tissues. Pectate lyases and lysine domain proteins probably play an important role during the switch to necrotrophy and the colonization of host tissues during the necrotrophic phase.

Cusions & Perspectives:
The *C. kahawae* genome described in this study can serve as a resource for better understanding the pathogen population evolution as well as the pathogenic mechanism that allows *C. kahawae* to infect green coffee berries.

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S2-O-10

Diversity and Dynamics of Fungal Endophytes in Coffee: Implications for Plant Health and Agriculture

Castillo Gonzalez Humberto[1, 2] (HUMBERTO.CASTILLOGONZALEZ@UNITS.IT), Alvarado Eduardo[3], Yarwood Stephanie[4], Chaverri Priscila[1, 5]

[1] *Department of Plant Science and Landscape Architecture, University of Maryland, College Park, Maryland, United States* ; [2] *Department of Chemical and Pharmaceutical Sciences, University of Trieste, Trieste, Trieste, Italy*; [3] *Centro para el Desarrollo de Alternativas Orgánicas, CoopeTarrazú, San Marcos de Tarrazú, San Jose, Costa Rica* ; [4] *Department of Environmental Science and Technology, University of Maryland, College Park, Maryland, United States* ; [5] *Centro de Investigaciones en Productos Naturales and Escuela de Biologia, University of Costa Rica, San Jose, San Jose, Costa Rica*

Rationale:
Fungal endophytes play a crucial role in plant microbiomes and significantly impact plant health and fitness. However, our understanding of their interactions, especially in relation to plant domestication and agricultural practices, is limited. Domestication may have altered the microbiomes and the range of associations possible in managed ecosystems compared to the wild. This study aims to investigate the influence of geography, coffee variety, and farming practices on the taxonomic and functional diversity of leaf endophytes in coffee. It also seeks to assess the impact of domestication on foliar microbiome diversity and identify potential interactions among fungal groups.

Methods:
We collected leaves from multiple coffee plants in Costa Rica, representing diverse coffee varieties and different agricultural management practices. We also examined the impact of shade/sun exposure and analyzed both newly emerged and mature leaves. Using culture-dependent and independent techniques, including ITS2 nrDNA metabarcoding with IonTorrent, we assessed the taxonomic composition and functional characteristics of fungal communities. The UNITE database and several bioinformatic tools were utilized for comparing these communities to previously characterized wild Rubiaceae endophyte communities.

Results:
Mature leaves and conventionally grown plants exhibited higher fungal diversity compared to newly emerged leaves and organically grown plants. Coffee variety had a relatively modest influence on fungal diversity. Surprisingly, sun exposure had a negligible impact, indicating the need to investigate the role of agroforestry practices further. Comparison with wild Rubiaceae communities revealed lower species richness in coffee leaves but similar taxonomic groups. Habitat preferences and potential interactions among identified fungal groups were observed.

Conclusions & Perspectives:
This study provides valuable insights into the interactions among fungal endophytes in coffee plantations and forests. Our findings underscore the significant influence of management practices on shaping fungal communities in cultivated crops and further emphasize the impact of domestication on phytobiome diversity. Understanding the influence of agricultural practices on fungal endophyte diversity can inform future research aimed at engineering endophytic communities through breeding or management strategies. These findings hold important implications for the preservation and enhancement of fungal endophyte diversity in coffee production systems.

S2-O-11

Potential association of HCF164, a chloroplast nuclear-encoded thioredoxin-like protein, with *Coffea* S_H9 resistance factor against *Hemileia vastatrix*

Guerra-Guimarães Leonor[1, 2] (leonorguimaraes@edu.ulisboa.pt), Pinheiro Carla[3, 4], Oliveira A. Sofia F.[5], Mira-Jover Andrea[6, 7], Valverde Javier[8, 9], Guedes Fernanda A.F. Guedes[8], Azevedo Herlander[10, 11, 8], árzea Vitor[1, 2], Muñoz-Pajares Antonio Jesús[12, 6, 8]

[1] *CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia (ISA), Universidade de Lisboa, Oeiras, Portugal*; [2] *LEAF--Linking Landscape, Environment, Agriculture and Food Researcenter,and ssociated Laboratory TAgronomia, Universidade de Lisboa, Lisboa, Portugal*; [3] *UCIBIO Applied Molecular Biosciences Unit, Department of LifeSciences,, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [4] *Associate Laboratory i4HB Institute for Health and Bioeconomy, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [5] *Center for Computational Chemistry, School of Chemistry, University of Bristol, Bristol, United Kingdom*; [6] *Departamento de Genética, Universidad de Granada, Granada, Spain*; [7] *Área de Ecología, Departamento de Biología Aplicada, Universidad Miguel Hernández, Elche, Spain* ; [8] *CIBIO, Centro de Investigação em Biodiversidade e Recursos Genéticos, InBIO Laboratório Associado, Campus de Vairão, Universidade do Porto, Vairão, Portugal* ; [9] *Estación Biológica de Doñana, Consejo Superior de Investigaciones Científicas (CSIC), Sevilla, Spain*; [10] *BIOPOLIS Program in Genomics, Biodiversity and Land Planning, CIBIO, Campus de Vairão, Vairão, Portugal* ; [11] *Departamento de Biologia, Faculdade de Ciências, Universidade do Porto, Porto, Portugal*; [12] *Research Unit Modeling Nature, Universidad de Granada, Granada, Spain*

Rationale:
Coffee leaf rust, caused by *Hemileia vastatrix*, is one of the diseases most significantly affecting Arabica coffee production on a global scale. Previous studies of coffee-*H. vastatrix* interactions have identified nine coffee resistance factors, designated as S_H1 to S_H9. Considering the significance of primary carbon metabolism in plant fitness and coffee-*H. vastatrix* interactions, the chloroplast represents a prime target for pathogen manipulation. In this study we have performed whole genome sequencing of coffee genotypes to explore the connection between chloroplast and coffee resistance S_H factors.

Methods:
The chloroplast genome of 42 coffee genotypes from the CIFC collection with different resistance factors to *H. vastatrix* was sequenced and de novo assembled. A chloroplast phylogenetic haplotype network was performed. An *in-silico* analysis of 132 selected nuclear-encoded protein families acting on chloroplasts, focusing on gene families previously highlighted as being involved in *H. vastatrix* resistance, was also performed.

Results:
No maternal inheritance of coffee resistance factors throughout the chloroplast genome was evidenced. Indeed, the chloroplast phylogenetic haplotype network clustered individuals per species instead of per S_H factors. Nevertheless, it was possible to verify for the first time that *C. arabica* is the maternal parent of the Híbrido de Timor (HDT), a spontaneous hybrid between *C. arabica x C. canephora*. From all the 132 proteins analysed, only the thioredoxin-like membrane protein HCF164 was able to discriminate between individuals with and without the S_H9 factor. Thioredoxins are known to play crucial roles in redox regulation and defence mechanisms in plants and the lack of the thioredoxin domain and redox-active disulphide center in the HCF164 protein found in S_H9 individuals could potentially have functional implications.

Conclusions & Perspectives:
Our work reinforces the role of chloroplast-mediated defences against leaf rust and introduces an unexplored strategy for identifying protein/genes associated with S_H factors and candidate targets of *H. vastatrix* effectors, thereby creating new perspectives for coffee breeding programs.

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		Nutrient acumulation in bean of diferent Coffea arabica cultivars in the mountains of Gorongosa National Park – Moçambique
SALVADOR	Henzo	Nutrient accumulation in fruits of 20 Coffea canephora genotypes
SUBRAMANIAN	Siva	Effect of Variety, Leaf Type & Processing Conditions on Sensory & Antioxidant content of Coffee Leaf Black Tea

Session 7 - Roasted coffee Technology & Processing

Last name	First name	Title of poster
CHUNG	Hsiao-Yen	The Exploration of Coffee Roasting Profiles with Estimation of Chlorogenic Acid and Caffeine in Roasted Coffee Beans
MOJICA	Ruel	Development, Piloting and Commercialization of Premium Coffee Blends
PIERL	Dennis	Optimal Control of Coffee Roasting Processes with Model Predictive Control
SUZUKI	Taroh	Impact on Sensory Quality and Physicochemical Changes in Coffee during Re-roasting

Session 8 - Coffee Chemistry & Sensory sciences

Last name	First name	Title of poster
GUINARD	Jean-Xavier	Coffee Cuality 2.0 – New cupping, drip brew, cold brew and espresso evaluation designs, protocols and analyses
K. N.	Aswathi	Biovolatile fingerprinting of honey/pulped natural coffee with Saccharomyces cerevisiae fermentation
KATHURIMA	Cecilia	Cup quality profiles of kenyan coffee processed by innovative methods
LEITÃO	António	The combined effects of shade and altitude on the quality of coffee beans grown at Gorongosa Mountain, Mozambique
LIM	Lik Xian	Validation of a New Coffee Cold Brew Method through Combined Central Location Tests and a Modified Conjoint Analysis and Focus Groups with Cold Brew Consumers and Brewers
PETRONILHO	Sílvia	Assessment of roasted coffee adulteration with coffee husks by gas chromatography and electronic tongue
SPEER	Karl	Food Authenticity — HPLC determination of 16-O-methylcafestol of instant coffees
		Food Authenticity — Determination of 16-O-methylcafestol content of green and roasted coffee — HPLC-method ; Method Validation Study of CEN/TC-460 WG 3
SEVERINI	Carla	Impact of superheated steam roasting process on the in-cup quality of espresso coffee brews
WELDEMICHAEL	Getachew	Genotype by environment interaction and stability of Ethiopian coffee (Coffea arabica L.) genotypes collected from Wollega Coffee growing areas for quality attributes

Session 9 - Consumption-Health & Safety

Last name	First name	Title of poster
IWAI	Kazuya	Effects of coffee-derived chlorogenic acids on postprandial serum triglyceride Levels - A Randomized, double-blind, placebo-controlled, crossover study -

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Sensory quality evaluation to produce excellent specialty arabica coffee derived from Indonesian germplasm collection

Akbar Miftahur Rizqi (miftahur.ra@gmail.com), Dwi Nugroho, Ari Wibowo, Yusianto Yusianto

Indonesian Coffee and Cocoa Research Institute, Jember, East Java, Indonesia

Rationale:
The expanding recognition and consumption of specialty coffee in the last few decades have led to the emergence of sustaining and potentially augmenting the economic feasibility of this coffee bean variety production. This has prompted breeding initiatives to prioritize the enhancement of beverage quality. This study proposes a selection approach for a large number of coffee accessions in germplasm collection which may help assess numerous genotypes in breeding programs focused on beverage quality and sensory profile.

Methods:
Over three years, 198 Arabica coffee accessions from the Indonesian Coffee and Cocoa Research Institute germplasm collection in Jember, Indonesia, were sensory characterized after wet postharvest processing. The sensory analysis of the beverage was conducted by three expert tasters following the protocol of the Specialty Coffee Association of America (SCAA, 2015). The sensory analysis encompassed aroma, flavor, aftertaste, acidity, body, balance, overall, uniformity, sweetness, and cleanliness (which was rated on a scale of 0 to 10 points each). Specialty coffees scored 80 or more on the sum of 10 sensory attributes. Specialty coffees scored from 85 to 89.99 is considered excellent. The sensory scores of the accessions were compared with check varieties (S795). Subsequently, the accessions that achieved superior scores than check varieties were subjected to cluster analysis using SAS software version 9.4.

Results:
Through the proposed method, the check variety (S795) obtained a total score of 83.00, and there were 123 accessions exhibiting a higher total score than the control. The cluster analysis result revealed the best coffee accession cluster with a mean total score of 86.37. Within this cluster, five accessions had excellent beverage quality according to the SCAA classification and had strong values across all sensory attributes. The accessions demonstrated favorable characteristics, including a spicy, caramel, floral taste and a bright acidity type. All the accessions in this group were selected as prospective accessions for further testing.

Conclusions & Perspectives:
We concluded that the selection strategy produced promising genotypes for excellent specialty arabica coffee. The effectiveness of this strategy is due to the use of well-known check varieties as preliminary selection and exceptional care in experimental precision throughout the entire procedure. These accessions were planted in the field to assess their adaptability and increase the production of such coffees. Furthermore, the five selected accessions are crossed with elite cultivars to generate new segregation.

References:

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Characterization of morphophysiological responses of *Coffea arabica* L. genotypes from the germplasm bank in the dry season

Almeida Julieta Andrea Silva de[1] (julieta.almeida@sp.gov.br), Torres Guilherme Almussa Leite[2], Moreira Roberto[3], Pantano Angélica Prela[4], Mistro Júlio César[3], Satorres Elaine Mantovani[3]

[1] *Centro de Café 'Alcides Carvalho', Instituto Agronomico de Campinas, Campinas, São Paulo, Brasil* ; [2] *Instituto de Geografia, Universidade Estadual de Campinas (UNICAMP), Campinas, São Paulo, Brazil* ; [3] *Centro de Café 'Alcides Carvalho', Instituto Agronômico de Campinas, Campinas, São Paulo, Brazil* ; [4] *Centro de Biossistemas Agrícolas e Pós-Colheita, Instituto Agronômico de Campinas, Campinas, São Paulo, Brazil*

Rationale:
The Arabica coffee tree has a strong presence in the economic and social scenario, occupying extensive areas of cultivation in Brazil. But this thriving production system could be threatened by drought resulting from global warming [1]. The development of drought-tolerant cultivars can contribute to minimize this difficulty. For this, it is important to know the developmental biology of *Coffea arabica* genotypes. The Coffee Germplasm Bank of the Instituto Agronômico has a high number of genotypes that are not known for their tolerance to drought. This study aimed to characterize the morphophysiological responses of *C. arabica* genotypes in the dry season.

Methods:
For this study, plants of different genotypes of *C. arabica* belonging to the Coffee Germplasm Bank were used. These plants are distributed in Field 1 and Field 2, both located in an experimental area at Fazenda Santa Eliza, at the Instituto Agronômico in the city of Campinas, SP, Brazil, latitude -22.8750816º, longitude 47.0753271º and altitude of 696 meters. The two fields have a total of 4000 plants that are arranged in rows, with a spacing of 70 cm. These plants were evaluated in relation to plant height, canopy diameter, leaf wilt symptoms and vigor in the dry season of the year.

Results:
The evaluations carried out in the dry season of 2021 show that Field 1 had a higher percentage of plants with a height greater than 1 m, stem diameter above 0.50 m and high vigor compared to those belonging to Field 2. However, Field 2 had a rate of 0.14 % of plants that remained without any symptoms of leaf wilt while in Field 1 all had partial wilting, 15.05 %, or complete wilting, 84.95 %.

Conclusions & Perspectives:
The results obtained indicate that there is the possibility of identifying genotypes with drought tolerance capacity. However, to achieve this identification there is a need for more evaluations of plants in the dry season.

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Direct somatic embryogenesis capacity of decaffeinated *Coffea arabica* L. genotypes

Almeida Julieta Andrea Silva de[1] (julieta.almeida@sp.gov.br), Silvarolla Maria Bernadete[2], Mistro Júlio César[2], Coelho Paulo Sérgio Da Silva[3], Satorres Elaine Mantovani[2]

[1] *Centro de Café 'Alcides Carvalho', Instituto Agronômico de Campinas, Campinas, São Paulo, Brasil* ; [2] *Centro de Café 'Alcides Carvalho', Instituto Agronômico de Campinas, Campinas, São Paulo, Brazil* ; [3] *Centro de Horticultura, Instituto Agronômico de Campinas, Campinas, São Paulo, Brazil*

Rationale:
Coffee farming does not have a naturally decaffeinated coffee cultivar. The coffee breeding program of the Instituto Agronômico has plants of hybrids and genotypes under selection with low caffeine content resulting from crosses. The multiplication of these genotypes by seeds is not adequate due to genetic segregation, which can be obtained by direct somatic embryogenesis. This process allows obtaining genetically identical plants. Thus, this study aimed at the vegetative multiplication of *Coffea arabica* genotypes in F3 generation of selection by direct somatic embryogenesis.

Methods:
Leaves collected from thirteen genotypes of *C. arabica* plants in the F3 generation and from the Obatã and Catuaí Vermelho cultivars belonging to the low-caffeine breeding program of the Agronomic Institute were used. Explants obtained from these leaves were subjected to direct somatic embryogenesis. For this purpose, culture medium with ½ the concentration of MS [1] salts and the addition of 20 g/L of sucrose and 10 µM of 2-Isopentenyladenine were used [2]. The culture medium was gelled with 5 g/L of agar or 2 g/L of Phytagel. Each treatment consisted of ten replications.

Results:
The explants of all genotypes were able to respond to the direct pathway with the formation of somatic embryos. However, in general, the number of embryos was higher for the explants that were in the medium solidified with Phytagel compared to the one with agar. On the other hand, genotypes 2, 7 and 14 had a lower number of somatic embryos in the presence of agar and Phytagel.

Conclusions & Perspectives:
All genotypes showed direct somatic embryogenesis capacity. The solidification agents Agar and Phytagel affected the formation of somatic embryos by the direct route. In addition, it is also noteworthy that agar and Phytagel alter the osmotic potential of the culture medium, which indicates that this factor participates in the control of the occurrence of direct somatic embryogenesis of *C. arabica*.

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Regulatory elements in coffee flower evocation related genes are responsive to temperatures principally

Angelo Paula CS (paula.angelo@embrapa.br)

Embrapa Coffee/IDR-Paraná, Londrina, PR, Brazil

Rationale:
Flower evocation occurs when plants make the transition from vegetative to reproductive meristems, in response to environment signals. Coffee flower evocation + flower bud emission are apart from anthesis by dormancy, and are responsive to different signals (Majerowicz and Söndahl 2005). A model for coffee phenology in southeastern Brazil became available (Camargo and Camargo 2001), which defines decreases in day length and temperatures as triggers to flower evocation. Flower evocation related *CONSTANS* (*CO*) and *FLOWERING LOCUS C* (*FLC*) genes are responsive to day length and vernalization, respectively. So, would *Coffea* spp. orthologs to these *Arabidopsis* genes display similar regulatory cis-elements?
Material & Methods:
C. canephora, *C. eugenioides* and *C. arabica* var. Caturra orthologs to *Arabidopsis FLC* and *CO* were identified. The relative numbers (cis-els/ortholog number) of temperature and light related cis-els identified (PLACE software) 1000 bps upstream the translation start codons were compared to those identified in *Arabidopsis* and to each other.
Results:
No significant difference was found between genera, regarding light or temperature related regulatory cis-els in *CO* or *FLC* promoters. Regardless, *CO* orthologs display higher frequency but lower diversity of temperature related cis-elements. By their turn, *FLC* orthologs also display more temperature than light related regulatory elements, but the temperature related elements are more diverse.
Conclusions & Perspectives:
Similarity to *Arabidopsis* regarding cis-elements indicate that both genera could respond to light and temperature controlling flower evocation. This characteristic fits the model proposed by Camargo and Camargo (2001). Despite absence of statistical significance, *FLC* genes are probably more responsive to temperatures than to light, as expected, and would be able to interact with a larger number of temperature related transcription factors. Surprisingly, *CO* orthologs also could respond strongly to temperatures, by interaction with a very reduced range of numerous transcription factors. Enhanced responsiveness to temperatures could grant coffee plants adaptability in the tropics, where temperatures can oscillate and display higher amplitudes than day length and flower evocation shall be impaired under hot long days.

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2. Majerowicz N, Söndahl MR 2005 Braz J Plant Physiol 17:247-254.

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Develop of F1 Hybrids of *Coffea Arabica* L. in Mexico to increase genetic resources and sustainable activity

Arrieta Noel[1] (narrieta@sfbaycoffee.com), Bracamontes Andros[2], Mora Rodolfo[3], Roblero Elizabeth[3]

[1] *Rogers Family Company, San Jose, Costa Rica* ; [2] *Rogers Family Company, San Francisco, USA* ; [3] *Rogers Family Company, Chiapas, Mexico*

Rationale:
Today Mexico coffee production receives an important boost at the initiative mainly of private companies. Currently, national production exceeds 3.5 million quintals and it is estimated that before reaching the year 2030, Mexico will be placed together with Brazil, Colombia and Honduras as the countries with the highest production in America. The state of Chiapas is the main producer and contributes approximately 40% of the total Mexican volume followed by the states of Veracruz with 30% and Oaxaca with 13%. The agro-ecological conditions offered by the extreme south of Mexico are suitable for coffee production, however, like Central America, production is constantly threatened by pests, diseases and extreme weather conditions. After the crisis caused by the impact of coffee rust in Mexico and Central America, the Rogers Family Company founded a breeding program with the aim of creating F1 hybrids with the best varieties adapted to this terroir.

Methods:
In Tapachula, Chiapas since 2021 year were crossed Geisha, Pacamara, Venecia and Centroamericano as a female genitor with Ruiru 11, ANACAFE 14, Icatu, Centroamericano and Mundo Maya as a male genitor. The objective is obtain new F1 hybrids families to initiate the individual evaluation and select finally the best according to their agronomic perfomance.

Results:
In the preliminary results, are some F1 hybrids families with greater productive potential, precocity and clear tolerance to coffee leaf rust, compared to the genitors planted in the same field also during this crop 2022-2023 was possible to collect fiel data and evidence the growth vegetative development, pests and diseases incidence, and cup quality with the first fruit harvest. The Pacamara x Ruiru 11, Pacamara x ANACAFE 14 and Geisha x Centroamericano are the first three population with outstanding results.

Conclusions & Perspectives:
The creation of new F1 hybrids will add more genetics resources, increase variability and offer to the international scenario the best genotypes to a sustainable coffee activity initiated by Mexico farmers.

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Validation and use of SNP markers for genetic compliance of commercial varieties in the coffee seed and nursery sectors

Barrera Lemus Santos[1] (santos@worldcoffeeresearch.org), Berny Mier Y Teran Jorge Carlos[2], Umaña Acosta Emilia[3], Alvarado Quintana Julio[4], Cruz Zeledon Jesslin[5], More Valdivia Jimmy[6], Castro Aguilar Elly[7]

[1] *Research and Development, World Coffee Research, Cali, Colombia* ; [2] *Research and Development, World Coffee Research, Merida, Yucatan, Mexico* ; [3] *Research and Development, World Coffee Research, Cartago, Costa Rica* ; [4] *Research and Development, World Coffee Research, Santa Ana, El Salvador* ; [5] *Research and Development, World Coffee Research, Matagalpa, Nicaragua* ; [6] *Research and Development, World Coffee Research, Tingo María, Peru* ; [7] *Research and Development, World Coffee Research, Jinotega, Nicaragua*

Rationale:
The seed and nursery sector plays a crucial role in providing millions of plants to coffee farmers, and it is essential that nurseries offer pure, genetically traceable, and high-quality plants to farmers. Relying entirely on phenotypic characterization to guarantee variety compliance can be problematic due to low phenotypic diversity, especially at the seedling stage. Therefore, genetic characterization through DNA markers has emerged as a reliable method to monitor genetic compliance. Kompetitive allele-specific PCR (KASP) SNP markers are becoming a favored option due to their cost-efficient, stable, accurate, and reproducible benefits as well as their high-throughput applications. To ensure accurate genetic compliance, using publicly available markers, it is essential to verify that the desired coffee varieties are reliably represented by the set of markers. The primary objective of this screening was to validate the markers at a larger scale and establish an accurate fingerprinting database that can be utilized as a practical tool to identify the authenticity of coffee varieties in the seed and nursery sectors.

Methods:
In order to confirm the dependability of publicly available SNP markers in representing the desired coffee varieties, we first selected the latest molecular markers published by Zhang et al. (2021), a total of 96 Arabica Coffee SNP markers. Subsequently, we further narrowed down the markers to a subset of 41 based on their ability to differentiate between multiple coffee varieties, as well as their high-throughput genotyping performance. After selecting the markers we sampled from various sources the most commonly cultivated Arabica coffee varieties in Latin America and Africa and established their SNP fingerprints.

Results:
The results of the survey indicate that there is a fingerprint variation both among and within varieties. This variation was observed in certain cases, likely because many coffee varieties are released at early generation stages (F4-F7), which lead to the presence of heterozygous, and segregating markers. Capturing this variation has allowed us to better identify the set of markers to use as a fingerprint for variety identification and nursery and seed production purity assessment.

Conclusions & Perspectives:
The fingerprinting database created from published SNP markers and adapted by WCR has proven to be a useful tool in identifying the authenticity of coffee varieties in the seed and nursery sector. Further research is needed to explore the potential of molecular characterization in developing new coffee varieties and preserving the genetic diversity of coffee.

References:

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Genetic diversity of Ethiopian commercial varieties and advanced selections of *Coffea arabica*: Desirable genes reservoir for heterosis breeding

Benti Tadesse[1] (tadessebenti@gmail.com), Endale Gebre[2], Kassahun Tesfaye[3], Gezahegn Berecha[4], Montagnon Christophe[5]

[1] *Ethiopian Institute of Agricultural Research (EIAR), Ethiopia;* [2] *College of Agricultural and Natural Resources, Michigan State University East Lansing, USA;* [3] *Bio and Emerging Technology Institute (BETin), Ethiopia;* [4] *Jimma University, College of Agriculture and Veterinary Medicine, Ethiopia;* [5] *RD2 Vision, Valflaunes, France*

Rationale:
The low genetic diversity and the narrow genetic base of commercial *C. arabica* cultivars has been reported in several previous studies. Genetic resources with similar category from Ethiopia were not included in those studies. Recent information with this regard would contribute towards understanding the existence of favorable genes for heterosis breeding.

Methods:
Recently published articles on molecular diversity of released varieties and promising selections of *C. arabica* are reviewed [1-4].

Results:
Genetic parameters calculated from allelic data of 14 SSRs markers revealed the presence of a high level of genetic diversity in Ethiopian released varieties and advanced selections of *C. arabica.* [2,3]. Estimation of genetic similarity based on the Jaccard's coefficient and the clustering patterns also showed similar results. While most of the genotypes from same geographical origin assigned either in the same cluster or closer, few individuals spread all over the tree.

Conclusions & Perspectives:
So far, few heterotic hybrid varieties have been released and distributed to the coffee farmers in Ethiopia. It is crucial to design heterosis breeding strategy to develop new origin-based and traceable hybrid varieties combining higher yield, typical flavor and resilient to the increasing negative effects of current climate change.

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2. Benti et al (2021). Genetic diversity among commercial arabica coffee (Coffea arabica L.) varieties in Ethiopia using simple sequence repeat markers. Journal of crop improvement, 35(2): 147-168.
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'Bola de Oro' a promising grafting method that creates a new Arabica tree architecture

Courtel Philippe[1] (bgbertrand3459@gmail.com), Breitler Jean Christophe[2], Alpizar Edgardo[1], Hidalgo Jose Martin[1], Bertrand Benoît[3]

[1] *ECOM, MATAGALPA, NICARAGUA* ; [2] *CIRAD, XALAPA, Mexico* ; [3] *CIRAD, MATAGALPA, Nicaragua*

Rationale:
There are several uses for grafting in fruit tree crop, including plant propagation. In addition to propagation, grafting can avoid a juvenile state, as an adult scion grafted onto a juvenile rootstock will maintain its adult state and ability to bear fruit.
Here we present a new grafting technique that deeply modifies the architecture of the plant, its precocity and its yield. we call it 'Bola de oro' for the shape in half-sphere that it confers to the plant.
Methods:
the grafting method 'Bola de oro' consists in grafting early a plagiotropic axis on a rootstock from seedling.
Results:
The architecture of the plant is deeply modified. The general form which is established from the 3rd year resembles a half-sphere of a diameter of 2 m and a height ranging between 1 m to 1.4 m. The precocity is remarkable since we observed a first bloom from the first year. The yield at 2-3-4 yrs seems superior to normal plants.
Conclusions & Perspectives:
We believe that Bola de Oro is a promising innovation that could increase the profitability of coffee growing. We now propose to study it in several edapho-climatic contexts.

Bola de oro grafting method. Right: 8 months after grafting; Left: 3 yrs old plant (flowering and producing).

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Resilience coffee cultivars: What does it mean? A Brazilian perspective

Bliska Flavia[1] (flavia.bliska@sp.gov.br), Guerreiro Filho Oliveiro[1], Montagnon Christophe[2], Serito Bianca[3], Ravaioli Giulia[3]

[1] *Coffee Center, Agronomic Institute, Campinas, São Paulo, Brazil* ; [2] *RD2 Vision, Montpellier, France* ; [3] *Lavazza Group, Turin, Italy*

Rationale:
The identification or selection of resilient coffee cultivars is an increasing priority for many coffee stakeholders. In an ecological system, resilience is understood as the ability of the population to absorb changes over time and still persist. However, there is not clear consensus for what is a resilient coffee cultivar and what should be the main selection criteria guiding breeders to select such cultivars. In our study, we applied a structured survey following the Delphi approach to reach a consensual definition of a resilient coffee cultivar.

Methods:
More than a hundred experts were interviewed. They belonged to two groups: i) scientists in natural science in general, agricultural scientists, including the coffee sector; and ii) coffee producers and professionals in the coffee sector (inclusive technical assistance and rural extension). The questions were very simple and straightforward: What are the inherent characteristics of a population of resilient plants? A resilient cultivar in general? A resilient coffee cultivar? They were also allowed to add comments. In line with Delphi approached, consensual definitions were sought. The research was approved by the Scientific Ethics Committee of the Instituto Agronômico and all respondents filled out the Terms of Free and Clear Consent.

Results:
Interestingly, the survey unveiled a coherent continuum of the resilience definition from plants in general [1], to cultivars and coffee cultivars. The adaptation to the environment and the capacity to recover from stresses was well established and remained when it was about cultivar. However, the novelty stood in the explicit mention of the chosen farming system as a major part of the environment for cultivars. The vegetative vigor, response to pruning, strong rooting system, and tolerance or resistance to biotic and abiotic stresses, are ranked amongst the major traits of coffee cultivars related to resilience

Conclusions & Perspectives:
The resilience of a coffee cultivar can be interpreted as its suitability to the environment, including its suitability to agronomic features and desired economic outcomes, especially high productivity. That is, it is not expected that coffee cultivars are universally resilient. This is a strong reminder for breeders that the selection of resilient varieties requires clarifying the necessary requirements of the corresponding cropping system.

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Multivariate Diagnosis of Nutrient Imbalances in and Production Constraints for *Coffea canephora* in the Congo Basin

Broeckhoven Ieben[1, 2, 3] (ieben.broeckhoven@kuleuven.be), Verbist Bruno[2], Merckx Roel[1, 3]

[1] *Div. of Soil and Water Management, Dep. of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium* ; [2] *Div. of Forest, Nature and Landscape, Dep. of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium* ; [3] *Plant Institute, KU Leuven, Leuven, Belgium*

Rationale:
This study aims to identify soil fertility constraints to Robusta (*Coffea canephora*) production and its corresponding gradients in plant nutritional status in the Tshopo Province, DRC. Identifying nutrient deficiencies and interactions using Compositional Nutrient Diagnosis (CND) is an efficient approach to improve fertilizer recommendations [1]. Moreover, differences in growth conditions, nutrient norms and interactions between Robusta and Arabica (*Coffea arabica*) indicate the need for localized and cultivar-specific nutrient norms [2]. Nonetheless, nutrient norms for Robusta are almost non-existing and inconclusive. This study aims to diagnose nutrient imbalances in Robusta coffee in the Tshopo Province, DRC, to contribute to the global knowledge on Robusta cultivation.

Methods:
Soil and coffee leaf samples were collected on 100 smallholder coffee plots. Composite soil samples were taken from the upper 25 cm at 5-10 different points per plot. The soil samples were analysed for pH, SOM content, total soil N, soil available P and S and soil exchangeable K, Ca, Mg [3]. Coffee leaf samples were taken from randomly selected plants within the plot. C*ritical leaf pairs* were collected during flowering [4]. Subsequently, leaf samples were analysed for macro- (N, P, K, Ca, Mg, and S) and micro-nutrient (Zn, Cu, Mn, Si, Co, B, Mo and Ni) content [3]. The coffee yield was estimated per plant as described by Idol et al. [5]. Nutrient imbalances were analysed using CND. The *high-yielding population* was identified following Khiari et al. [6], which was used to determine CND norms per nutrient.

Results:
Soil nutrients analyses showed significant interactions between soil pH and soil and leaf nutrients. In addition, significant interactions between soil fertility and macro-nutrient uptake were found. Using CND, critical macro- and micro-nutrient deficiencies were identified for Robusta coffee grown in the Tshopo province. Furthermore, CND norms were found to differ from those observed by DeBauw [7] and Wairegi [2].

Conclusions & Perspectives:
CND allowed for the identification of nutrient deficiencies and interactions for *Coffea canephora*. The identification of regional nutrient imbalances will enable farmers to optimize inputs by targeting the most critical nutrient deficiencies. Despite the crucial importance of soil fertility and nutrient imbalances, most coffee farmers in the Tshopo Province, DRC, would also benefit from improving agricultural practices, including pruning and pest and disease management, to advance their coffee production.

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Leaf rust and CBD resistance alleles identified in Amazonian Robusta coffee plants

Silva Ana Carolina Andrade[1] (carolandrade95@hotmail.com), Caixeta Eveline Teixeira[1, 2], Silva Letícia de Faria[1], Rocha Rodrigo Barros[3], Teixeira Alexsandro Lara[3]

[1] *Institute of Biotechnology Applied to Agriculture, Lab BioCafé, Universidade Federal de Viçosa - UFV, Viçosa, MG, Brazil* ;
[2] *Embrapa Café, Brazilian Agricultural Research Corporation–Embrapa; eveline.caixeta@embrapa.br, Brasília, DF, Brazil* ;
[3] *Embrapa Rondônia, Brazilian Agricultural Research Corporation – Embrapa, Porto Velho, RO, Brazil*

Rationale:
Coffee growing in the Western Amazon has undergone changes at the technological level, leading the state of Rondônia to second in the ranking of *Coffea canephora* production in Brazil. Although the *C. canephora* species carries genes for resistance to the main pathogens that affect coffee plants, studies show that there are different levels of resistance among the genotypes. In this regard, the identification of coffee plants with higher number of resistance alleles for the main diseases is essential to the Amazonian coffee sustainability to these diseases.

Methods:
In our work, 96 *C. canephora* genotypes were analyzed with molecular markers associated with resistance genes to *Hemileia vastatrix* (coffee leaf rust) and *Colletotrichum kahawae* (coffee berry disease-CBD). Of these coffee plants, 59 belong to the breeding program of the Brazilian Agricultural Research Corporation (Embrapa) in Rondônia, including clone cultivars and germplasm accessions. The other 37 coffee come from selection carried out by local producers. Purified DNAs from coffees were analyzed for five different loci associated with *H. vastatrix* resistance, and one locus monitored by two markers flanking the gene associated with *C. kahawae* resistance.

Results:
Molecular data allowed identifying coffee plants containing resistance alleles for both diseases, with emphasis on Clone N13, Clone N02 and Hybrid 16 BAG. These coffees have four pyramidal alleles for resistance to *H. vastatrix* and the allele for resistance to *C. kahawae*. We also found coffee genotypes with the SH3 gene, the only one that has not yet been supplanted by the *H. vastatrix*races in Brazil. Other genotypes showed different combinations of the six genes. Furthermore, coffee plants with the *C. kahawae* resistance gene can be selected for a preventive CBD breeding program in Brazil.

Conclusions & Perspectives:
The use of these molecular markers was efficient to identify coffee that present pyramided resistance alleles for both pathogens. When a genotype has pyramided resistance alleles, it increases performance stability in the environment. Thus, these coffee plants can be used as a source for durable resistance, since overcoming resistance by new pathogen races is difficult.

Key-words: Pyramiding of alleles - Molecular markers - Genetic breeding - *H. vastatrix* - *C. kahawae.*

Funding: CNPq, FAPEMIG, CBP&D/Café, INCT-Café and SEDEC

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Sensory evaluation of coffee varieties across two coffee agro-ecological zones in Kenya

Cheserek Jerono Jane[1] (jane.cheserek@kalro.org), Kathurima Wakigondi Cecilia[2], Gimase Mwita James[3], Mier Y Teran Berny Jorge[4], Maina Catherine[5]

[1] *Coffee Breeding, Kenya Agricultural and Livestock Research Organization, Nairobi, Nairobi, Kenya* ; [2] *Coffee quality, Kenya Agricultural and Livestock Research Organization, Nairobi, Ruiru, Kenya* ; [3] *Coffee Breeding, Kenya Agricultural and Livestock Research Organization, Nairobi, Ruiru, Kenya* ; [4] *Research, World Coffee Research, Portland, Portland, USA* ; [5] *Research, World Coffee Research, Nairobi, Nairobi, Kenya*

Rationale:
Coffee quality varies along the coffee value chain from bean size, sensory attributes, and biochemical characteristics. The quality of coffee beans is a critical factor during the marketing of coffee and it is a great determinant in setting up the final market prices. Quality is also one of the main factors considered during breeding programs and its importance is regarded as those of disease resistance and productivity. The study aimed at assessing different coffee varieties sourced from different coffee-growing countries and grown in Kenya on their sensory characteristics.

Methods:
Thirty-one (31) coffee varieties from different countries were established in two different sites in Kenya and evaluated for their liquor quality from the harvest of the years 2021 and 2022. The ripe cherry was harvested and processed through the wet processing method and dried to a moisture content of 10.5 to 11.5%. The beans were hulled, roasted, and allowed to cool for eight hours before grounding. The sensory evaluation was carried out using a panel of four trained cuppers. Sensory evaluation was carried out using different descriptors which include flavour, body, balance, acidity, fragrance/aroma, aftertaste, and preference. First, a Genotype-vs-Environment interaction (GGE) biplot was used for each site and year combination as an environment to visually inspect variety and environment patterns. A linear model using the effect of Variety, Site, and Year and its interactions, as well as the Cupper to estimate variances and significance testing was conducted. A linear mixed model using Variety, as a random effect to estimate BLUPs was also included.

Results:
GGE biplot divided the environments into three sectors, one with both years in Koru, and Ruiru 2021 and 2022 separately. This interaction was supported by the ANOVA on which the Variety by Site by Year interaction was highly significant. In addition, all the two-way interactions, and the single effect (except Year) were significant. Batian was the overall variety with the highest cupping score across both sites and years, nevertheless, Geisha was especially responsive in Koru, and SL28 in Ruiru, especially in 2021.

Conclusions & Perspectives:
The findings are significant for the double and triple interaction to underline the complexity of evaluating cupping quality. Although it is possible to identify high-quality varieties across environments, wider testing and identification of site-specific best performers would be needed to maximize cupping quality.

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Microscopic analysis of root cellular architecture in different coffee species: a preliminary comparison of the main phenotypical traits in controlled conditions

Crisafulli Paola[1] (paola.crisafulli@illy.com), Bordeaux Mélanie[2], Georget Frédéric[3], Lefort Eveline[3], Léran Sophie[3], Neumann Kerstin[4], Navarini Luciano[1]

[1] *illycaffè spa, Trieste, Italy* ; [2] *Fondation Nicafrance, Managua, Nicaragua* ; [3] *UMR DIADE CIRAD-IRD, Montpellier, France* ; [4] *IPK, Seeland, Germany*

Rationale:
In the last years, due to the climate change, much attention has been paid to coffee plant resilience and to agronomic solutions related to different stress tolerance in the field. In this perspective, the recently activated EU-funded BOLERO project will develop phenotyping tools, apply them to evaluate coffee root system architecture traits and root plasticity. Few descriptions of coffee root have been reported so far [1], especially in non-commercial species. This preliminary study aims to describe the main phenotypical root traits in different coffee plants kept under controlled conditions to deepen the knowledge and to possibly reveal interspecific differences.

Methods:
Lateral roots with radicles of 6 *Coffea* sp. young plants kept under greenhouse optimal conditions (*C. arabica*, *C. anthonyi*, *C. canephora*, *C. eugenioides*, *C. stenophylla*, *C. congensis*) were sampled, put in ethanol 50% and immediately delivered to illycaffé (Trieste, Italy). Fresh sections in agarose blocks were cut by hand and observed by optical and electronic microscopy. Specific histochemical techniques were used to highlight starch grains and suberin distribution.

Results:
The root primary cell architecture is quite the same for all the investigated species and it is composed by a raw of epidermal cells with hairs, an exodermis with suberin, 4-5 layers of cortical cells, a suberized endodermis and a central stele, from tetrarch to exarch. However, special cells traits characterized each species: peculiar 'window' cells are observed in *C. canephora* and *C. arabica* root exodermis, highly suberized. *C. arabica* xylem vessel are the greatest compared to the other species. *C. eugenioides* is characterized by large exodermis and cortical cells whereas *C. stenophylla* presents quite opposite characteristics. *C. congensis* is particularly rich in epidermal hairs and starch grains in the cortex cells.

Conclusions & Perspectives:
Coffee roots in primary structure are similar but the above-mentioned phenotypical traits could be differently affected under stress conditions. In facts, the 'window' cells presence in the exodermis increases the transport of nutrients and the suberin presence together with large cortical cells are associated to tolerance to drought. In view of these preliminary results, it will be interesting to discover the strategies adopted by various coffee spp. root cells in response to abiotic or biotic stresses [2, 3].

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Addressing climate change in coffee farming: development of a methodology to select for drought tolerance in coffee varieties

Darracq Olivier[1] (olivier.darracq@rdto.nestle.com), Léran Sophie[2], Aberkane Hafid[1], Palacios Algenis[3], Castillo Jonny[3], Bordeaux Mélanie[3], Marie Lison[2], Arigoni Fabrizio[1], Etienne Hervé[2], Bertrand Benoit[2], Marraccini Pierre[2]

[1] *Coffee and Cocoa Department, Nestle Research Center, Tours, France* ; [2] *UMR DIADE, CIRAD, Montpellier, France* ; [3] *Finca la Cumplida, Nicafrance Foundation, Matagalpa, Nicaragua*

Rationale:
Climate change is posing many challenges that are affecting coffee production worldwide. Among them, drought periods are observed more frequently, and the annual precipitation are becoming more unpredictable in many coffee producing countries. In this context, breeding for drought tolerant varieties is becoming necessary to sustain future coffee production. However, drought tolerance is a complex trait which requires the combination of different disciplines to improve selection efficiency. With the aim to define a universal methodology to phenotype *C. arabica* and *C. canephora*for drought tolerance, Nestlé and CIRAD initiated a multidisciplinary project to define reliable traits to assess coffee drought tolerance rapidly and cost-effectively in both controlled and field conditions. The outcomes of the project Madgic will be a list of reliable traits that could be used.

Methods:
A contrasted set of *C. arabica* and *C. canephora* genotypes were tested under controlled conditions (France) and semi-controlled conditions (Nicaragua) using a common protocol combining visual annotation, detailed phenotyping and physiological analyses. After a period of acclimatization, coffee plants were subjected to water withdrawal and compared to irrigated plants (unstressed control). Morphological and physiological traits were collected at the beginning of the experiment, during drought stress and recovery period. Data were analyzed to study the drought effects on different traits, and to subset the most discriminant traits in each experiment.

Results:
The results showed that our experimental dispositive allowed to discriminate the two coffee species tested. In fact, they responded differently to drought, *C. arabica* cultivars being generally more sensitive to drought than tested *C. canephora*clones. Some traits associated with leaf number and area, were more affected by drought than others, and consequently appeared more powerful to identify tolerant and susceptible plants. The results also showed Near Infra-Red (NIR) as a powerful non-destructive proxy to monitor the leaf water content.

Conclusions & Perspectives:
A phenotyping methodology is proposed combining low cost, portable tools to be deployed in different testing conditions. Some traits such as the total leaf number and leaf area, leaf inclination are suitable for early screening of large populations, while others (selected branch leaf number, NIR, drought visual score) can also be recommended in the field for long term evaluation of drought. A limited number of data recording taken at the right time appeared sufficient to follow the establishment of drought and select tolerant coffee candidates coping this stress.

In vitro tissue cultures from *Coffea arabica*: from callus to cell suspension

Di Bonaventura Azzurra[1] (dibonaventura.azzurra@spes.uniud.it), Marchetti Stefano[1], Petrussa Elisa[1], Braidot Enrico[1], Navarini Luciano[2], Suggi Liverani Furio[2], Zancani Marco[1]

[1] *Department of Agricultural, Food, Environmental and Animal Sciences, University of Udine, Udine, Italy* ; [2] *illycaffé S.p.A, Trieste, Italy*

Rationale:
Beyond the popular beverage, coffee (*Coffea* spp.) has a potential application in medical and cosmetic fields as a source of phytochemicals. Plant tissue culture provides an eco-friendly option for large-scale production of high-value secondary metabolites (SMs). Cell suspension cultures (CSCs) are mostly aimed for this purpose as widely demonstrated for many medicinal and aromatic plants. So far, a clear and well-defined protocol for the induction of non-embryogenic and friable callus is still missing for *C. arabica*, hampering the possibility to develop a viable CSC.

Methods:
Leaf discs from *C. arabica* cv. Bourbon Red and Castillo were placed on a full-strength MS medium supplemented with different concentrations and types of plant growth regulators (i.e., cytokinin, CK, and auxin, AUX). The percentage of callusing and the mean fresh weight of explant+callus (mFW_{e+c}) were measured for each treatment. The callus texture was also considered. After calli transfer in liquid media, CSCs were stabilized into fine suspensions, and cell growth was monitored every 3-4 days by both fresh and dry weight measurements. Cell viability was determined every 7 days.

Results:
Regardless the cv., 1 mg L−1 of both CK and AUX gave the highest value of mFW_{e+c} and friable calli. The mFW_{e+c} measured in CK-free media were significantly different from the others, showing the lowest values. Treatments with different CKs exhibited significant differences in mFW_{e+c}, being KT the best combination in terms of weight and friable consistency. Significant differences of mFW_{e+c} were also observed between cultivars and type of AUX. No calli, or very reduced ones, were present in media supplemented with some AUXs, like β-NOA, IAA, IBA and NAA. 2,4,5-T was the best AUX both in terms of mFW_{e+c} and friable texture. The growth pattern of CSCs displayed a typical sigmoidal shape, with an initial lag, followed by clearly defined exponential and stationary phases, with a high percentage of viable cells.

Conclusions & Perspectives:
1 mg L−1 of both KT and 2,4,5-T was found to be the best combination for callus induction and CSC establishment. These procedures could be extended to other *Coffea* cultivars and species and several elicitation conditions will be applied on CSCs to induce the synthesis of bioactive compounds.

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Genetic Differentiation of *Coffea liberica* Using SSR Marker Analysis

Fabella Jermaine Marie Ann (jermaine.fabella15@gmail.com), Baltazar Miriam

Genetics Laboratory, Research Center, Cavite State University, Indang, Cavite, Philippines

Rationale:
C. liberica, popularly known as "Kapeng Barako" in the Philippines has been a growing interest since the past decade due to the rise of specialty coffee. Although specialty coffee is associated with Arabica, the unique flavors of *C. liberica* increase the range of flavors available for coffee consumers. There are two groups of *C. liberica* recognized by the International Plant Names Index (IPNI, 2005), *C. liberica* var. *liberica* (Liberica coffee), and *C. liberica* var. *dewevrei* (Excelsa coffee). As there is no clear system to authenticate and classify the two, morphology-based characterization is the usual method to use. The present study was conducted to characterize *C. liberica* var. *dewevrei* (Excelsa) and *Coffea liberica* var. *liberica* (Liberica) accessions using Simple Sequence Repeats (SSR) marker or microsatellite.

Methods:
A total of 93 accession of *C. liberica* collected from from CvSU-NCRDEC field gene bank and demo areas were used in the study. Morphological characterization was initially used to classify the two varieties. The extracted DNA were amplified using 16 SSR primer-pairs. Polymorphic markers were analyzed using similarity index, cluster analysis and PIC.

Results:
Based on the result, all primers showed polymorphism across *C. liberica*. It generated a total of 68 alleles with an average of 4.25. The polymorphism information content (PIC) obtained varied between 0.603 (M306) to 0.203 (CM5). Out of the 16 polymorphic markers, only 2 shows to be highly informative (PIC> 0.50) namely M3016 and M310 while the rest of the markers is moderately high informative (0.25>PIC>0.5) except for M326 and CM5.

The cluster analysis revealed a 2 major groups. Cluster 1 composed of a group of 6 Excelsa with 1 Liberica that branch together with 4 other Liberica accession. Cluster 2, on the other hand, composed of 2 subclusters. The result variability revealed the introduction and traditional use of seeds as planting materials in the country, causing the high genetic and phenotypic variability among accession. The information of the study also aids to improve the method of classification between these two known varieties.

Conclusions & Perspectives:
The use of SSR markers was revealed the base line information on the diversity of *C.liberica*in the country. The results explored the taxonomic relationship between the two distinct group. Despite the age of this marker technology, the SSR markers is still an informative and reliable method for classification. It is still a useful tool in developing coffee cultivars for commercial puposes and varietal registration.

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Genetic Variation and Association among Quality Attributes of Arsi Coffee (*Coffea arabica* L.) Collections at Mechara, eastern Ethiopia

Girma Sintayehu (girmasintayehu@gmail.com)

Coffee Improvement, Oromia Agricultural Research Institute, Mechara, Oromia, Ethiopia

Ethiopia is naturally endowed with a suitable climate for the production of high quality coffee. Arsi coffee is known to produce Harar C coffee quality grade and known for its unique flavor and aroma. However, the genetic variability and diversity of coffee accessions collected from Arsi is not studied. Therefore, this study was conducted to assess the genetic variability of Arsi coffee for bean quality traits and to determine the associations among bean quality traits. A total of 60 genotypes were evaluated for bean physical and organoleptic coffee quality traits . The analysis of variance results showed significant variation among Arsi collections for all traits except astringency, bitterness, odor and single bean weight. The overall quality of Arsi coffee collections was in the range between 75.83 and 87.17%. Genotypic and phenotypic coefficient of variation ranged from 2.61 to 34.83% and 2.97 to 35.67%, respectively. The heritability in broad sense and genetic advance as percent of mean ranged from 32.50% to 99.88% and 3.94 to 70.15%, respectively. Most of the coffee quality traits had high heritability. The overall coffee quality had positive and significant phenotypic and genotype correlations with aromatic intensity, aromatic quality, acidity, body, flavor, overall standard quality and overall cup quality. All these traits through overall standard quality, and aromatic intensity, aromatic quality and acidity via each other and through body and flavor exerted positive direct effects on overall coffee quality at genotypic level. Based on un-weighted pair group method of classification the 60 genotypes were grouped into 14 clusters of which Cluster I was the largest consisted of 26 (43.33%) collections while other clusters consisted of 1 to 8 genotypes. Principal components (PCs) showed that the first seven PC explained 79% of the total variance of which PC1, PC2 and PC3 contributed 27, 19 and 10%, respectively. The Euclidean distances of 1770 pair of genotypes ranged from 2.0 to 12.06 with 6.79, 1.51 and 22.2% overall mean standard deviation and coefficient of variation, respectively. The Arsi coffee collections with high mean values for varied number of coffee beans physical and organoleptic quality traits distributed across clusters. The research results suggested the higher chance of selection of genotypes to be developed as varieties for high coffee quality and for crossing of distant collections with distinct quality traits to produce hybrids with high coffee quality.

Keywords: Cluster - Cup quality - Euclidian distance - Genetic Advance - Heritability.

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Evolutionary history of three *Baracoffea* species from western Madagascar

Guyot Romain[1] (romain.guyot@ird.fr), Bezandry Rickarlos[2], Perla Hamon Perla[1], Dupeyron Mathilde[1], Sabatier Sylvie[3], Anest Artemis[3], Ranarijaona Hery Lisy Tiana[4], Vavitsara Marie Elodie[4]

[1] *DIADE, IRD, Montpellier, France* ; [2] *Ecole Doctorale sur les Ecosystèmes Naturels (EDEN), Ecole Doctorale sur les Ecosystèmes Naturels (EDEN), Mahajanga, Madagascar* ; [3] *AMAP, CIRAD, Montpellier, France* ; [4] *Ecole Doctorale sur les Ecosystèmes Naturels (EDEN), Mahajanga, Madagascar*

Rationale:
The genus *Coffea* comprises a total of 130 species, of which 79 are native to the Indian Ocean islands such as Comoros, Mauritius, Reunion and Madagascar. This considerable number of species in IOI, suggest an intense diversification in this territory in a relative short time (Hamon et al., 2017). Among these *Coffea* species there is an atypical group composed of 9 species: The Baracoffea 'alliance' found exclusively in the tropical dry forests of western Madagascar and restricted to sandy soils. However, to date, very few information exist about their evolutionary history and few molecular data are available in public repositories.

Methods:
Plant Material: *Coffea ambogensis* J.-F.Leroy ex A.P.Davis & Rakotonas., *C. boinensis* A.P.Davis & Rakotonas. *and C. bissetiae* A.P.Davis & Rakotona, collected at the Antsanitia village, Ankarafantsika National Park and the Ankarafantsika region, respectively.
Illumina sequencing: HiSEQ 2500, 2X150 bp.
Plastid genome reconstruction and nuclear SNP calling: Plastid genome reconstruction was done similar to Charr et al., 2021.
Phylogenetic analyses: The maternal and nuclear phylogeny was reconstructed similarly to Charr et al., 2021.
Environmental parameters: Climatic data were extracted from GPS coordinates of each species and from WorldClim information (http:// www.worldclim.org).

Results:
In this study, we produced genomic sequences for three Baracoffea species: *C. ambongensis* (14.7 Gbp), *C. bissetiae* (13.8 Gbp) and *C. boinensis* (17.5 Gbp). Complete chloroplast genomes were assembled, and 28,800 nuclear Single Nucleotide Polymorphism markers were recovered to construct maternal and nuclear phylogenies of *Coffea* including Baracoffea species. The phylogenetic trees obtained indicate the monophyly of Baracoffea species supporting the taxonomy proposed by Davis et al., 2008. The nuclear phylogeny of *Coffea* species from Madagascar indicates the divergence of Baracoffea with a group of species originating from the north of Madagascar and belonging to the Subterminales serie (*C. augagneuri*, *C. ratsimamangae*, *C. pervilleana* and *C. vahemarensis*). Climatic data when associated to the nuclear phylogenetic tree indicate an adaptation of Baracoffea to dry environment ~7 Mya.

Conclusions & Perspectives:
Baracoffea species have diverged from species of the subterminate series species 7 Mya, adapting to high temperatures and solar radiation as well as low annual rainfall. Further genomic and comparative analyses with the *C. canephora* genome (Denoeud et al., 2014) will be carried out in the future to identify the repertoire of Baracoffea-specific genes and investigate their putative adaptation-related function.

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Identification of resistance sources to root-knot nematode *Meloidogyne paranaensis* in wild accessions of *Coffea arabica* from Ethiopia

Ito Dhalton Shiguer[1] (ito@idr.pr.gov.br), Shigueoka Luciana Harumi[2], Sera Tumoru[2], Diazzi Guilherme Rainho[2], Dorigo Orazilia França[1], Florencio Tanara Garcia de Novaes[1], Dos Santos Debora da Silva[1], Sera Gustavo Hiroshi[2]

[1] *Plant Protection Department / Laboratory of Nematology, Paraná State Institute for Rural Development, Londrina, Parana, Brazil* ; [2] *Plant Breeding Department / Laboratory of Coffee Genetics, Paraná State Institute for Rural Development, Londrina, Parana, Brazil*

Rationale:

The root-knot nematodes (*Meloidogyne* spp.) are one of the major pathogens of coffee plants. *Meloidogyne paranaensis* causes significant damage to coffee cultivation in several countries.

There are few *Coffea arabica* cultivars with resistance to *M. paranaensis*. It is very important to identify new resistance sources to this nematode. Currently, this can be found in wild accessions of *C. arabica* from Ethiopia.

The Institute of Rural Development of Paraná - IAPAR-EMATER (IDR-Paraná) has 130 wild accessions from Ethiopia. Eight accessions were identified with high resistance to *M. paranaensis* in previous surveys. The objective of this study was to evaluate the levels of resistance to *M. paranaensis* in wild accessions from Ethiopia from IDR-Paraná's coffee germplasm bank.

Methods:

The experiment was conducted in a greenhouse at IDR-Paraná in Londrina, Paraná, Brazil setted up in a completely randomized design with 32 wild accessions from Ethiopia, eight replicates and one plant per plot. The cultivar IPR 106 was the resistant standard and 'Mundo Novo IAC 376-4' the susceptible control.

The seedlings were inoculated with 1000 eggs and J2 mL^{-1} of *M. paranaensis* (Initial Population = IP) obtained by Bonetti & Ferraz method (1981).

Evaluations were performed 120 days after inoculation, obtaining the final population (FP). The reproduction factor (RF) was calculated considering resistant treatments below 1.0. The reduction in the reproduction factor (RRF) was used to classify the resistance level from highly susceptible (HS) to highly resistant (HR).

Results:

The RRF showed 20 accessions classified as HR with RF values lower than the resistant control 'IPR 106'. One genotype was classified as Resistant (R), and eight as Moderate Resistant (MR), indicating these accessions may have intermediate resistance. Three accessions were classified as Susceptible (S) or HS, showing RF values similar to or higher than the susceptible control 'Mundo Novo'. Only four accessions were classified as HR and had RF values lower than 1.0.

Conclusions & Perspectives:

It is known there is a great genetic variability among accessions of *C. arabica* from Ethiopia. Other studies have identified several good agronomic characteristics, such as resistance to nematodes *M. incognita* and *M. exigua*, bacterial blight disease, Coffee Berry Disease, drought tolerance, quality of taste, and low caffeine. Global coffee breeding programs have been exploring this genetic variability widely.

The four highly resistant accessions will be used by breeding programs to develop new cultivars associated with other important characteristics.

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Dynamics of photosynthetic pigments of elite genotypes of *Coffea arabica* L. undergoing drought in interaction with enhanced air [CO_2]

Martins Joana I.[1, 2] (jis.martins@campus.fct.unl.pt), Reis Fabrício O.[3], Leitão António E.[1, 2], Rodrigues Ana P.[1], Silva Maria J.[1, 2], Marques Isabel[1], Lidon Fernando C.[2], Ribeiro-Barros Ana I.[1, 2], Ramalho José C.[1, 2]

[1] *PlantStress&Biodiversity Lab, Centro de Estudos Florestais, Lab. Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras e Lisboa, Portugal* ; [2] *Unidade de Geobiociências, Geoengenharias e Geotecnologias, Faculdade de Ciências e Tecnologia, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal* ; [3] *Universidade Estadual do Maranhão, São Luís-MA, Brazil*

Rationale:
Drought severity affects the physiological and biochemical processes of coffee plants, including pigments associated with the photosynthetic apparatus (chlorophyll *a* and *b*; carotenoids as zeaxanthin and lutein) [1]. In the context of expected climatic change scenarios, here we explored the impact of single and combined exposure to drought and elevated [CO_2] in the photosynthetic pigments of *C. arabica* L. plants.

Methods:
Plants from *C. arabica* L. *cvs*. Geisha 3 (G3), Marsellesa (Mar), and their Hybrid (Hy) were grown for 2 years under controlled environmental conditions (RH: 70%; irradiance: *ca*. 700 µmol m^{-2} s^{-1}; photoperiod: 12h; temperature: 25/20°C (day/night); air [CO_2]: 400 (aCO_2) or 700 (eCO_2) µL CO_2 L^{-1}, under well-watered (WW) conditions, were gradually submitted to mild (MWD, Ψ_{pd}, -1,2 to -1,5 MPa) and severe (SWD, Ψ_{pd}, -2,5 to -3,0 MPa) conditions. WW conditions were then re-established, followed by a 2-week recovery period (Rec14). Photosynthetic pigment content was assessed in newly mature leaves ([2]).

Results:
Drought reduced the total content of chlorophylls and carotenoids in aCO_2 in all genotypes, except in the carotenoid content in Hy under SWD, but showed a mitigated impact under eCO_2. Despite total carotenoid decline, among the most important photoprotective carotenoids, zeaxanthin content increased in all genotypes under SWD, greater under eCO_2 than aCO_2 in Mar and Hy. Regardless [CO_2], only Hy plants showed greater lutein content under SWD, as compared with their WW plants. By Rec14, total carotenoid and chlorophylls content decreased in Hy under both [CO_2], while it were maintained/increased in Mar and increased/maintained in G3, respectively, as compared with their SWD conditions.

Conclusions & Perspectives:
Results indicated that eCO_2 may contribute to a better status of the photosynthetic apparatus of plants under severe drought, therefore contributing to improve of energy dissipation. On the other hand, different recovery ability to SWD was observed among the genotypes.

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Responsiveness of the antioxidative enzyme system to drought and its interaction with increased air [CO_2] in elite genotypes of *Coffea arabica* L.

Martins Joana I.[1,2] (jis.martins@campus.fct.unl.pt), Reis Fabrício O.[3], Rodrigues Ana P.[1], Leitão António E.[1,2], Silva Maria J.[1,2], Marques Isabel[1], Lidon Fernando C.[2], Ribeiro-Barros Ana I.[1,2], Ramalho José C.[1,2]

[1] *PlantStress&Biodiversity Lab, Centro de Estudos Florestais, Lab. Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, 2784-505 Oeiras e 1349-017 Lisboa, Portugal* ; [2] *Unidade de Geobiociências, Geoengenharias e Geotecnologias, Faculdade de Ciências e Tecnologia, Universidade NOVA de Lisboa, 2829-516 Caparica, Portugal* ; [3] *Universidade Estadual do Maranhão, São Luís-MA, 65081-400, Brazil*

Rationale:
Coffee crop sustainability may be threatened by drought severity. Therefore, it is crucial to characterize the physiological/biochemical mechanisms that allow drought tolerance, in interaction with expected elevated air [CO_2] (eCO_2) that was reported to mitigate drought impacts [1]. Here, we explored the role of antioxidative mechanisms in the response of *C. arabica* L. exposed to drought and eCO_2.

Methods:
Plants from *C. arabica* L. *cvs*. Geisha 3 (G3), Marsellesa (Mar), and their Hybrid (Hy) grown for 2 years under controlled environmental conditions (RH: 70%; PPFD: *ca*. 700 µmol m^{-2} s^{-1}; photoperiod: 12h; temp.: 25/20°C, day/night; air [CO_2]: 400 (aCO_2) or 700 (eCO_2) µL CO_2 L^{-1}, under well-watered (WW) conditions, were gradually submitted to mild (MWD, Ψ_{pd}, -1,2 to -1,5 MPa) and severe (SWD, Ψ_{pd}, -2,5 to -3,0 MPa) conditions. WW conditions were then re-established, followed by a 2-week recovery period (Rec14). Cellular antioxidative enzymes activitiy (superoxide dismutase, SOD; ascorbate peroxidase, APX; glutathione reductase, GR; catalase, CAT) was assessed in newly mature leaves ([2]).

Results:
Enzymes activity usually increased in droughted plants, with some differences across genotypes and [CO_2]. Gradual drought promoted enzyme activity, excepted on APX in Mar and CAT and GR in Hy. The eCO_2 amplified such response as regards APX (G3, Mar), GR (Mar), CAT (Hy), or reduced it for SOD (Mar), APX (Hy) and CAT (G3, Mar), as compared with WW plants. By Rec14, these enzymes activity did not differ from SWD values, regardless of [CO_2] and genotype.

Conclusions & Perspectives:
The antioxidative system is clearly involved in drought response to control reactive oxygen species presence. The eCO_2 alters enzyme response to drought. With a few exceptions, under SWD the eCO_2 plants usually showed similar or greater activities than aCO_2 counterparts. The maintenance of increased activities by Rec14 pointed to a persistence of the need for antioxidative protection or a "vaccine" type of response, which is relevant in the context of coffee response to the expected climate changes.

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Genetic Variability of Coffee (*Coffea arabica* L.) Germplasm in biennial bearing and its influence on selection efficiency

Merga Dawit[1] (dawitmerga@gmail.com), Beksisa Lemi[1], Merga Wakuma[2], Alemayehu Desalegn[1], Addisu Melaku[1], Tefera Fekadu[1], Benti Tadesse[1], Ayano Ashenafi[1]

[1] *Plant Breeding and Genetics, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia* ; [2] *Plant Breeding and Genetics, Ethiopian Institute of Agricultural Research, Tepi Agricultural Research Center, Tepi, South west Ethiopia, Ethiopia*

Arabica coffee is a perennial cash crop and highly affected by biennial bearing which decreases farmers' annual income and world's coffee industries. Developing non-biennial bearing variety is prominent in addition to management practices. This study was conducted from 2012 to 2020 in Southwestern Ethiopia at Tepi and Gera to test the extent of genetic variability among Arabic coffee Germplasm in biennial bearing and to understand the influences of bienniality on advanced selection. The pooled analysis of variance revealed handiness of genetic variability in yield and biennial bearing. Moderate genotypic coefficient of variation (10-20%), heritability (30-50%) and high genetic advance as percentage of mean (>20%) were manifested in yield and biennial bearing. Response to selection and selection efficiency were negatively affected by biennial bearing. Early selection, excluded 30-40% of the top high yielders from advanced selection. Selection at four harvesting seasons revealed 90% and more selection efficiency. Thus, one has to be conscious the alternate bearing nature of lines during advanced selection. Both T-43/11 and T-51/11 were among the top high yielders and had shown low biennial bearing at Gera and Tepi. T-33/11, T-49/11, T-55/11 and T-61/11 had shown very low biennial bearing at both locations. These promising lines are recommended for further biennial bearing improvement breeding programs. In general, there is a possibility to select the genetic materials for almost null in biennial bearing.

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Tailoring the deployment of market-driven coffee varieties in Rwanda from the international multilocational varietal testing

Mvuyekure Simon Martin[1, 2] (msmartin202@gmail.com), Berny Jorge[3], Gatarayiha Celestin[4], Kayonga Julianne[5]

[1] *Traditional Export Crops, Rwanda Agriculture and Animal Resources Development Board (RAB), Kigali, Rwanda* ; [2] *World Coffee Research, Portland, Oregon, USA* ; [3] *World Coffee Research, Portland, USA* ; [4] *Inter-African Coffee Organization, Abidjan, Côte d'Ivoire* ; [5] *Starbucks' Farmer Support Center, Kigali, Rwanda*

Rationale:
Rwanda is one of the countries whose economy heavily relies on agricultural exports commodities, while coffee account for 11.8%% of total agricultural export earnings [1]. To address current and future challenges in the coffee supply chain there is a need to transform coffee farming from subsistence farming to more market-led high productivity systems [2]. The deployment of new coffee varieties needs, imperatively, to consider farmer´s' and market preferences to maximize the return on investment from multi-actor stakeholders.

Methods:
The Rwanda Agriculture an Animal Resources Development Board is a partner in World Coffee Research´s International Multi-Location Variety Trial. WCR located and gathered 31 top-performing coffee varieties from 11 suppliers around the world. The varieties, most of which have never been tested on a broad basis, were distributed to coffee growing countries, for long-term evaluation on research plots. Twenty eight of these varieties are being evaluated in Rwanda for yield, quality and tolerance/resistance to biotic and abiotic stresses in three different locations of Rwanda. Trial locations are characterized by Mid altitude and low rainfalls (Huye), Low altitude and raw rainfalls (Ngoma) and Mid altitude and high rainfalls (Nyamasheke). Field performance of each of the varieties was evaluated through GGE biplot analysis to assess adaptability and stability potential of varieties across the study location. Multivariate biplots was performed to identify correlation between variables.

Results:
With regards to farmer and consumer preferences [3], the polygon view generated by GGE biplots revealed varieties which have a wide adaptability potential for yield. The vertex varieties IPR107, SLN 5B, S4808, Paraneima and Pacamara showed a to top yielding potential and site specific adaptability. Other varieties such as RABC 15 (local variety), Batian, S795, Geisha and AB3. Varieties such as Col 4, EC 15, RABC 15, Col 2, and Ruiru 11 were consistently less susceptible to CBD across the sites where as Geisha, Pacamara H1, and Marsellesa were highly susceptible to rust. The Multivariate biplot revealed good varieties for yield and quality attributes (S4808, SLN5B, RABC15, S795, Batian and Geisha). Other varieties such as Col 2, Pacamara, EC15, Marsellesa and Ruiru 11, showed relatively low yielding potential and high quality attributes.

Conclusions & Perspectives:
These finding are breakthroughs in varietal evaluation, introduction and adoption programs with regards to minimization of the cost of production, maximization of the production in efforts to ensure the future of the supply chain with regard to market demand.

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Genome Wide Association Studies in *Coffea arabica* for resistance to *Meloidogyne incognita*

Ponce Talita[1, 2] (talitapponce@hotmail.com), Ariyoshi Caroline[2, 3], Machado Andressa[4], Felicio Mariane[3], Shigeoka Luciana[5], Sera Gustavo[5], Pereira Luiz Filipe[2, 6]

[1] *Universidade Estadual de Londrina, Londrina, PR, Brazil* ; [2] *Plant Biotechnology Lab, Instituto de Desenvolvimento Rural do Paraná, Londrina, PR, Brazil* ; [3] *Instituto Nacional de Ciência e Tecnologia (INCT), Londrina, PR, Brazil* ; [4] *Agronema-Análise, Consultoria e Experimentação Nematológicas,, Londrina, PR, Brazil* ; [5] *Plant Breeding, Instituto de Desenvolvimento Rural do Paraná, Londrina, PR, Brazil* ; [6] *Embrapa Café, Londrina, PR, Brazil*

Rationale:
The nematode *Meloidogyne incognita* causes significant damage to coffee production. Chemical and/or field practices to control this nematode are costly, therefore the use of resistant cultivars is the best alternative for it control. Most *Coffea arabica* cvs are susceptible to *M. incognita*, but genotypes collected from Ethiopia (FAO 1964) have revealed high resistance to this nematode. Exploring the variability of a diverse panel of coffea arabica genotypes, this study aimed to identify SNPs and genes associated with resistance to *M. incognita* in *Coffea arabica* through Genome Wide Association Studies (GWAS).

Methods:
Genotyping by Sequencing (GBS) of a collection of 159 *C, arabica* plants, mostly from FAO collection (FAO 1964) was used. Alignment was performed to the reference genome of *C. arabica* Et039 (SALOJÄRVI, 2021), to identify the SNPs. Phenotyping was performed in plants growing at greenhouse conditions inoculated with eggs and J1 stage of *M. incognita.* For each genotype, 8 a 12 plants were evaluated using reproduction factor, nematodes per gram of root, host susceptibility index, and Oostenbrink index. The association between the genotypic and phenotypic data was conducted using multilocus models using the mrMLM.GUI package (WANG et al., 2016) and GAPIT3 (WANG et al., 2021) in the R software.

Results:
Phenotyping identified 89 resistant and 31 susceptible plants by reproduction factor. GWAS was perfomed with 11,411 SNPs and 120 plants phenotyped, and 19 SNPs were associated with resistance to *M. incognita*. Five SNPs with the highest correlation values were selected. In linkage disequilibrium with these SNPs, 3 genes encoded an LRR receptor-like serine/threonine-protein kinase, 1 gene encoded a WRKY transcription factor, and 1 gene encoded a Pathogenesis-related protein.

Conclusions & Perspectives:
In this study, the identification of loci related to resistance to *M. incognita* was performed. This characterization can be useful in guiding the breeding process and also as a target for genetic editing. SNPs will be validated using the Taqman® method for marker-assisted selection. Staining techniques will investigate gene response during plant-pathogen interaction and nematode development in roots, providing insights into coffee's resistance to *M. incognita* nematode.

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Transcriptome analysis of flowers from irrigated *Coffea arabica* plants

Fabian Thiely[1] (fabian_thi@hotmail.com), Sánchez-Barrantes Elodia[2], Ivamoto-Suzuki Suzana[3], Pereira Luiz Filipe[4], Gatica-Arias Andres[2]

[1] *Pós-Graduação Bioinformáática, UTFPR -Cornélio Procópio, Cornélio Procópio, PR, Brazil* ; [2] *Escuela de Biología, Universidad de Costa Rica, San Jose, Costa Rica* ; [3] *Centro de Ciências Agrárias, Universidade Estadual de Londrina, Londrina, PR, Brazil* ; [4] *Embrapa Café, Brasilia, DF, Brazil*

Rationale:
Floral development is a crucial factors affecting productivity and quality of coffee, and it is highly influenced by environmental conditions. To investigate the processes that impact plant flowering we perform a transcriptome analysis of flowers collected from different parts of the plant under irrigated and non-irrigated water stress conditions.

Methods:
Flowers from *C. arabica* L cv Catuaí Vermelho, from plantations located at the Costa Rican Coffee Institute in São Pedro de Barva de Heredia, Costa Rica, were collected at various developmental stages, different plant heights, and under irrigated and non-irrigated conditions. RNA-seq data was analyzed using the Galaxy platform, using *C. arabica* Caturra (*NCBI*, 2070241) as genome reference for alignment of reads and gene annotation.

Results:
Initially, flowers from non-irrigated plants collected from three plant regions - apical, medial, and basal – were compared and revealed 92 genes that were differentially expressed between the apical and medial regions, 58 genes between the apical and basal regions, and 151 genes between the medial and basal regions. A second comparison involved flowers from irrigated plants in the medial and apical regions, which were compared to flowers from non-irrigated plants in the same respective regions. We observed a higher number of upregulated genes in flowers from irrigated plants, both in the medial region (450 genes) and the apical region (293 genes).In another comparison, between flowers from irrigated and non-irrigated plants, we observed 322 differentially expressed genes, with 289 genes positively regulated in irrigated plants, of which 281 were exclusive to irrigated plants. Among the upregulated genes under irrigated conditions, several corresponded to genes known to be overexpressed under water stress, such as stress-induced protein K1N2-like, nsLTPs, and late embryogenesis abundant protein 1-like. Overall, the analysis identified a greater number of differentially expressed genes in the flowers of irrigated plants.

Conclusions & Perspectives:
Those results provided a panel of differentially expressed genes, both under irrigated/non-irrigated conditions, as well as in different parts of the plant. Understanding the modulation of gene expression under such conditions can greatly contribute to the development of effective strategies for crop management and breeding, ultimately enhancing *C. arabica*'s tolerance to water deficit.

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Biochemical and transcriptional characterization of genes related to diterpene biosynthesis in *Coffea eugenioides*

Ivamoto-Suzuki Suzana Tiemi[1] (suzanatiemi@yahoo.com.br), Aprígio Nícollas Gabriel De Oliveira[2, 3], Zambrana Gustavo De Oliveira[1], De Brito Danilo Ribeiro[2], Kitzberger Cintia Sorane[3], Pereira Luiz Filipe[2, 3, 4]

[1] *Universidade Estadual de Londrina, Londrina, PR, Brazil* ; [2] *Pós Graduação Genética e Biol Molecular, Universidade Estadual de Londrina, Londrina, PR, Brazil* ; [3] *IDR Paraná, Londrina, PR, Brazil* ; [4] *Plant Biotech Lab - IDR Paraná, Embrapa Café, Londrina, PR, Brazil*

Rationale:
Brazil is the largest producer and exporter of coffee in the world and to keep this position it is essential to improve the product quality continuously. The biochemical concentration of sugars, caffeine, trigonelline, chlorogenic acids and lipids directly influence the beverage quality. Cafestol (CAF) and kahweol (KAH) are lipids from the diterpene class related to coffee organoleptic characteristics [1]. Despite its importance, the genes involved in the biosynthesis of CAF and KAH in coffee plants are still unknown. The aims of this study were to identify and determine the expression of diterpene synthases (diTPS) involved in the diterpene biosynthesis pathway. In addition, we also determine the biochemical profiles of CAF and KAH in fruits and leaves of *C. eugenioides.*

Methods:
Data from public transcriptome (RNA-seq) were used to identify diTPS genes [2]. Digital expression profiles of *C. eugenioides* diTPS were obtained by aligning the RNA-seq nucleotide sequences against the *C. eugenioides* genome using the Kallisto software. Diterpenes (CAF and KAH) were extracted from leaves and fruits of *C. eugenioides* and the biochemical profile was determined by high performance liquid chromatography (HPLC).

Results:
The transcriptome data showed a total of 16743 genes, of which 5 were identified as diTPS (2 *CeCPS*, 1 *CeKS* and 2 *CeKO*) and were selected for expression analysis. Thus, it was possible to observe that the diTPS showed a higher transcriptional activity in fruits than in leaves. Furthermore, the quantification of diterpenes indicated the presence of KAH only in fruits, while CAF was observed in leaves and fruits.

Conclusions & Perspectives:
Our results corroborates with the hypothesis that the diterpene concentration for each tissue is probably modulated by the expression of these diTPS genes. The results of this study can help the understanding of diterpenes roles in coffee quality. In the future, it might provide estrategies for coffee breeeding programs with the objective of producing plants with desirable levels of CAF and/or KAH.

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Response of Coffee (Coffea arabica L.) Varieties to Heat Stress at the Seedling Stage

Rago Daba Etana[1, 2] (dabaetana2018@gmail.com), Tamirat Wubishet[1], Kufa Taye[1], Bayata Adugna[3]

[1] *Coffee Agronomy Research, Ethiopian Institute of Agricultural Research; Jimma center, Jimma, Oromia, Ethiopia* ; [2] *Environmental Management, University of Ibadan, Ibadan, Oyo, Nigeria* ; [3] *Soil Laboratory Research, Ethiopian Institute of Agricultural Research; Jimma center, Jimma, Oromia, Ethiopia*

Rationale:
Even though, coffee is one of the most socioeconomically important crops, it is susceptible for environmental variations [1]. The heat effect is an indirect consequence of high temperatures often caused by the accumulation of greenhouse gases. This is derived from the long-wave refraction and reflection of radiation. Heat causes morphological deformation, malfunction growths, and normal plant physiological growth disturbances in coffee growths. There is not yet information on the responses of the released Ethiopian Arabica coffee varieties to heat stresses. This study aimed to investigate the responses of released coffee varieties to heat stress under controlled environments.

Methods:
This was studied at the greenhouse of Jimma Agricultural Research Center (JARC) by using randomized complete block designs with three replications of nine coffee varieties (six hybrids, and three pure lines). During the study, temperature and relative humidity in the greenhouse had been taken consecutively for the study period. The leaf color, growth, and physiology parameters were taken and subjected to analysis of variances (ANOVA) for statistical variation studies.

Results:
The average temperatures and relative humidity in the greenhouse showed huge variations from the normal recommended for coffee growths. ANOVA results revealed significant differences among coffee varieties in leaf discoloration scoring, suckering, and physiological parameters to heat stress. **Three** of the nine varieties showed leaf scratches, discoloration, and sclerosis more than the others, while the **two varieties** showed fewer responses in leaf color changes. Similarly, four varieties generated the highest number of suckers with fewer dead branches. However, two varieties produced less number of suckers with normal branches.

Conclusions & Perspectives:
Overall, different responses of released Arabica coffee varieties revealed showed the possibility to develop heat resistance varieties in the future by using crop improvement techniques. Furthermore, a study in relation to the genetic role and biochemical constituents needs advanced and deeper exploration.

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Indirect Somatic Embryogenesis of *Coffea arabica var Geisha* and N39-6 Variety Using Leaf Explants

Ramadhani Fatuma (fatumajumapili09@gmail.com), Mwaipopo Rehema, Mbwebwe Nuhu, Mtenga Damian, Monyo Grace, Kilambo Deusdedit

Crop improvement, Tanzania Coffee Research Institute (TaCRI), Kilimanjaro, Tanzania

Rationale:
Coffea arabica is the most popular specie of coffee which is utilized worldwide in the food, pharmaceutical, and cosmetics industries. The somatic embryogenesis technique promotes the micropropagation of several coffee species for the commercial production of plantlets (1). However, this technique depends on the genotype of a particular plant for successful regeneration (2). The current study aimed to create a protocol for the multiplication of *Coffea arabica* var. Geisha and N39-6 varieties using somatic embryogenesis.

Methods:
Young leaves from Geisha and N39-6 were collected from the field at the Lyamungu site, followed by surface sterilization using a 3.5% V/V calcium hypochlorite solution for 30 min, and rinsed three times with sterile distilled water. After removing the margins and midribs, the leaves were excised into small pieces of around 1 cm2. Leaf explants were then planted on Murashige and Skoog (MS) supplemented with several concentrations of 2,4-dichlorophenoxyacetic acid (2,4-D), 6-(3,4-dimethylallylamino) purine (2 IP), 6-benzyl amino purine (BAP), and 30 g/L sucrose to activate indirect somatic embryogenesis.

Results:
One month after initiation, the results showed that explant planted onto 2,4-D (0.5 mg/L), 2IP (2 mg/L) and 30 g/L sucrose induced callus formation both in the N39-6 and Geisha explants. Explant transferred to MS media with 2,4-D (1 mg/L), BAP (4 mg/L) and sucrose (30 g/L) promoted indirect somatic embryos in both N39-6 and Geisha explants, and active proliferation was observed on the N39-6 explant after 3 to 6 months. MS media containing BAP (1.125 mg/L) and sucrose (30 g/L) stimulated N39-6 and Geisha somatic embryos to form globular and torpedo embryos. The half concentration of MS media supplemented with Biotine (0.01 mg/L) and BAP (0.112 mg/L) promoted the change of globular embryos to the cotyledonary stage and root formation in both explants.

Conclusions & Perspectives:
The preliminary results of this study suggested that somatic embryogenesis may be a viable method for the micropropagation of Coffea arabica var. Geisha and N39-6 variants. Nevertheless, it is crucial to standardize these conditions and follow appropriate acclimatization practices to ensure that leaf explants procreate new calli and produce many plantlets from the leaf explant.

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Transcriptomic effects of drought and the positive effect of elevated CO2 in promoting tolerance in two *Coffea sp.* genotypes

Marques Isabel[1] (isabelmarques@isa.ulisboa.pt), Fernandes Isabel[2], Paulo Octávio S.[2], Lidon Fernando C.[3], L. Partelli Fábio[4], Damatta Fábio M.[5], Ribeiro-Barros Ana I.[6], Ramalho José C.[6]

[1] *Centro de Estudos Florestais, Laboratório Associado TERRA, ISA/University of Lisbon, Lisboa, Lisboa, Portugal* ; [2] *cE3c-Center for Ecology, Evolution and Environmental Changes and CHANGE, Universidade de Lisboa, Lisboa, Portugal* ; [3] *Unidade de Geobiociências, Geoengenharias e Geotecnologias (GeoBioTec), Faculdade de Ciências e Tecnologia (FCT), Universidade NOVA de Lisboa (UNL), Caparica, Portugal* ; [4] *Centro Universitário do Norte do Espírito Santo (CEUNES), Universidade Federal Espírito Santo (UFES), São Mateus, Brazil* ; [5] *Departamento de Biologia Vegetal, Universidade Federal Viçosa, Viçosa, Brazil* ; [6] *Centro de Estudos Florestais, Laboratório Associado TERRA, ISA/University of Lisbon, Lisboa, Portugal*

Rationale:
Drought is a major constraint to plant growth and productivity worldwide and will aggravate with predicted climate changes. Although elevated air [CO2] might mitigate some of these effects in plants, the mechanisms underlying the involved responses are poorly understood in woody economically important crops such as *Coffea*. Transcriptome analyses were used to unveil adjustments to increasing drought severity and how eCO2can modify such adjustments. Based on the fact that eCO2 improves resilience to drought at the physiological and biochemical levels, we hypothesized that eCO2 interacts at the transcriptomic level to promote a greater metabolic performance, and acclimation mechanisms, namely at the photosynthetic level.
Methods:
The impact of drought at the transcriptomic level was assessed on the leaves of two cropped *Coffea* sp. genotypes (*C. canephora* cv. Conilon Clone 153, CL153; *C. arabica* L. cv. Icatu Vermelho), which were grown under ambient (aCO2) or elevated (eCO2) air [CO2], and well-watered (WW), moderate (MWD) or severe (SWD) water deficit [1].
Results:
Expression levels and regulatory pathways were barely affected by MWD, while the SWD condition led to a down-regulation of most differentially expressed genes (DEGs). eCO2attenuated the drought impact in the transcripts of both genotypes but mostly in Icatu, in agreement with physiological and metabolic studies. A predominance of protective and reactive oxygen species (ROS)-scavenging-related genes, directly or indirectly associated with ABA signaling pathways was found in *Coffea* responses.
Conclusions & Perspectives:
Icatu and CL153 showed different regulatory mechanisms in response to drought, with minor effects of MWD and the positive action of eCO2. Still, a clear effect on photosynthetic pathway was found, namely under SWD and eCO2, contrary to previous physiological and biochemical studies.

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Next-Generation proteomics suggests a higher antioxidative tolerance to drought in *Coffea arabica* than in *Coffea canephora* genotypes

Marques Isabel[1] (isabelmarques@isa.ulisboa.pt), Gouveia Duarte[2], Martins Sónia[3,4], Semedo Magda C.[3,4], Lidon Fernando C.[4], Damatta Fábio M.[5], Ribeiro-Barros Ana I.[1], Armengaud Jean[2], Ramalho José C.[1]

[1] *Centro de Estudos Florestais, Laboratório Associado TERRA, University of Lisbon. Instituto Superior de Agronomia, Lisboa, Portugal* ; [2] *Département Médicaments et Technologies pour la Santé (DMTS), Université Paris-Saclay, CEA, INRAE, SPI, Bagnols-sur-Cèze, France* ; [3] *Departamento de Engenharia Química, Instituto Superior de Engenharia de Lisboa, Instituto Politécnico de Lisboa, Lisboa, Portugal* ; [4] *Unidade de Geobiociências, Geoengenharias e Geotecnologias (GeoBioTec), Faculdade de Ciências e Tecnologia (FCT), Universidade NOVA de Lisboa (UNL), Monte da Caparica, Portugal* ; [5] *Departamento de Biologia Vegetal, Universidade Federal Viçosa, Viçosa, Brazil*

Rationale:
Understanding the role of proteins in the response of plants to drought is crucial to unveil the acclimation mechanisms and to contribute to assist breeding programs to obtain tolerant cultivars. Advances in next-generation proteomics offers a quick and accurate molecular approach to identify proteins and reveal pathways associated with the physiological responses of biological systems to abiotic stress conditions.

Methods:
A label-free proteomic approach was used to deepen the knowledge regarding the underlying mechanisms by which two cropped *Coffea* sp. genotypes (*C. canephora* cv. Conilon Clone 153, CL153; *C. arabica* L. cv. Icatu Vermelho) respond to moderate (MWD) and severe (SWD) water deficits [1].

Results:
About 3000 proteins were identified in both genotypes, but less than 0.8% contributed to *ca*. 20% of proteome biomass. Proteomic changes were dependent on the drought severity level, being stronger under SWD and with an enrolment of different proteins, functions, and pathways than under MWD. The two genotypes displayed stress-responsive proteins under SWD, but only *C. arabica* showed a higher abundance of proteins involved in antioxidant detoxification activities.

Conclusions & Perspectives:
Overall, the impact of MWD was minor in the two genotypes, contrary to previous studies. In contrast, an extensive proteomic response was found under SWD, with *C. arabica* having a greater potential for acclimation/resilience than *C. canephora*, as regards these genotypes. This was supported by a wider antioxidative response and an ability to repair photosynthetic structures. This important information will help to develop new elite genotypes that assure coffee supply under water scarcity levels.

Acknowledgements: Funding support from the European Union's Horizon 2020 research and innovation program (grant agreement No 727934, project BreedCAFS), and from national funds from Fundação para a Ciência e a Tecnologia, I.P. (FCT), Portugal, through the project PTDC/ASP-AGR/31257/2017, through the Scientific Employment Stimulus—Individual Call (CEEC Individual)—2021.01107.CEECIND/CP1689/CT0001 (IM), and through the research units UIDB/00239/2020 (CEF), and UIDP/04035/2020 (GeoBioTec), and the associated laboratory TERRA (LA/P/0092/2020). Fellowships from CNPq (Brazil), and the FAPEMIGl (project CRA-RED-00053-16), to F.M. DaMatta are also greatly acknowledged.

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Protective mechanisms and chloroplast membrane lipid changes in response to drought and elevated air [CO_2] in *Coffea* spp.

Semedo José N.[1, 2] (jose.semedo@iniav.pt), Rodrigues Ana P.[3], Leitão António E.[2, 4], Pais Isabel P.[1, 2], Dubberstein Danielly[5], Partelli Fábio L.[6], Scotti-Campos Paula[1, 2], Silva Maria J.[2, 3], Marques Isabel[3], Reboredo Fernando H.[2], Lidon Fernando C.[2], DaMatta Fábio M.[7], Ribeiro-Barros Ana I.[2,3], Ramalho José C.[2,4]

[1] *Unidade de Investigação em Biotecnologia e Recursos Genéticos, Instituto Nacional de Investigação Agrária e Veterinária, I.P., Oeiras, Portugal* ; [2] *Centro de Geobiociências, Geoengenharias e Geotecnologias, FCT NOVA, Caparica, Portugal* ; [3] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [4] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal* ; [5] *CEUNES, Departamento Ciências Agrárias e Biológicas, Universidade Federal Espírito Santo, São Mateus, ES, Brazil* ; [6] *CEUNES, Departamento Ciências Agrárias e Biológicas, Universidade Federal Espírito Santo, São Mateus, Brazil* ; [7] *Departamento de Biologia Vegetal, Universidade Federal Viçosa, Viçosa, MG, Brazil*

Rationale:
Drought and elevated air [CO_2] are key players for crops productivity in a context of climate changes (CC), with direct impact on C-assimilation. Here we focused photosynthetic protective mechanisms and chloroplast membrane remodelling as key feature to *Coffea* spp. acclimation.

Methods:
Seven-year-old plants from *Coffea canephora* cv. Conilon (Clone 153) and *C. arabica* cv. Icatu, grown in 80 L pots, under controlled conditions (Temp., 25/20ºC, day/night; RH, 70%; irradiance, *ca*. 700 µmol $m^{-2}s^{-1}$; photoperiod, 12 h; air [CO_2]: 380 (aCO_2) or 700 (eCO_2) µL CO2 L-1) and well-watered (WW) conditions [1], were gradually submitted to mild (MWD, Ψ_{pd}, -1,2 to -1,5 MPa) and severe (SWD, Ψ_{pd}, -2,5 to -3,0 MPa) drought. Photosystem (PS) functioning, antioxidative molecules (*e.g.*, carotenoids, HSP70, ascorbate, superoxide dismutase, Cu,Zn-SOD; ascorbate peroxidase, APX; glutathione reductase, GR) were assessed in newly mature leaves Membrane integrity (I%) and chloroplast fatty acids (FAs) composition and their unsaturation (DBI) were also assessed.

Results:
In MWD, regardless of genotype and [CO_2], no PSII photoinhibition and membrane damage occurred. In SWD-aCO_2 negative impacts were evident in CL153. High Icatu resilience in SWD may result from enhanced photoprotection and antioxidative control mechanisms (greater zeaxanthin, lutein and ascorbate pools, and Cu,Zn-SOD and APX activities), HSP70, and increased *de novo*synthesis of FAs. Also, eCO_2 attenuated the impact of SWD in CL153 (lower chronic photoinhibition and I%), and both genotypes showed trends for further reinforcement of several protective elements (xanthophyll cycle pool, lutein, Cu,Zn-SOD, APX, ascorbate), of HSP70 (only in Icatu), and DBI decline (significant in CL153), as compared SWD-aCO_2 plants.

Conclusions & Perspectives:
Both genotypes showed relevant resilience to severe drought, supported by antioxidative mechanisms and chloroplast lipid matrix dynamics. eCO_2 mitigated the impacts in CL153 and enhanced drought response of Icatu, which is clearly relevant for *Coffea* sp. breeding under CC.

Acknowledgements: Funding support by EU Horizon 2020 research and innovation program (GA No 727934, proj. BreedCAFS), and national funds of Fundação para a Ciência e a Tecnologia, I.P., Portugal, through project PTDC/ASP-AGR/31257/2017, the Scientific Employment Stimulus-Individual Call (CEEC Individual) -2021.01107.CEECIND/CP1689/CT0001 (IM), the research units CEF (UIDB/00239/2020), GeoBioTec (UIDP/04035/2020), and associated laboratory TERRA (LA/P/0092/2020). Brazilian fellowships of CNPq to FLP, EC and FMD, and the FAPEMIG (project CRA-RED-00053-16, APQ01512-18), to F.M.D., are also greatly acknowledged

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Soluble sugar dynamics in leaves of two coffee genotypes (*C. arabica* and *C. canephora*) subjected to severe heat and/or drought

Pais Isabel P.[1, 2] (isabel.pais@iniav.pt), Leitão António E.[2, 3], Semedo José N.[1, 2], Dubberstein Danielly[4], Partelli Fábio L.[4], Lidon Fernando C.[2], Reboredo Fernando H.[2], Scotti-Campos Paula[1, 2], Marques Isabel[5], DaMatta Fábio M.[6], Ribeiro-Barros Ana I.[2, 7], Ramalho José C.[2, 7]

[1] *Unidade de Investigação em Biotecnologia e Recursos Genéticos, Instituto Nacional de Investigação Agrária e Veterinária, I.P., Oeiras, Portugal* ; [2] *Centro de Geobiociências, Geoengenharias e Geotecnologias, FCT NOVA, Caparica, Portugal* ; [3] *PlantStress & Biodiversity Lab., Centro Estudos Florestais,, Associado TERRA, Instituto Superior Agronomia, Universidade de Lisboa, Oeiras, Portugal* ; [4] *CEUNES, Departamento de Ciências Agrárias e Biológicas, Universidade Federal do Espírito Santo, São Mateus, ES, Brazil* ; [5] *PlantStress & Biodiversity Lab., Centro Estudos Florestais,, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [6] *Departamento de Biologia Vegetal, Universidade Federal Viçosa, Viçosa, MG, Brazil* ; [7] *PlantStress & Biodiversity Lab., Centro Estudos Florestais,, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal*

Rationale:
Coffee bean trade involves over 100 million people, and has a major economic and social impact worldwide. As climate change (CC) worsens, coffee plants become increasingly exposed to rising temperatures and drought events that greatly reduce C-assimilation [1], and limit growth, yield and coffee bean quality. In a context of CC, we highlight the effects of heat and/or drought in coffee leaf soluble sugars (SS).

Methods:
Seven-year-old plants of *C. arabica* L. cv. Icatu and *C. canephora* Pierre ex A. Froehner cv. Conilon (CL153), grown in 80 L pots, under controlled conditions (Temp., 25/20 ºC, day/night; RH, 70%; irradiance, *ca*. 700 µmol m-2s-1; photoperiod, 12 h; 380 µL CO2 L-1), were gradually exposed (3 weeks) to severe drought (SWD,) or maintained well-watered (WW), and afterwards submitted to a gradual temperature raise (up to 42/30 ºC; 0.5 ºC day-1). The effect on leaf SS was evaluated through HPLC (RI detector; Sugar-Pak 1 and DionexCarboPac PA1 columns, the 2nd one to resolve non-pure peaks from Sugar-Pak 1 separation).

Results:
There were no differences in total SS content in either genotype until 37ºC, but by 42 ºC the CL153-WW plants showed doubled contents. Severe drought (SWD) greatly increased total SS in both genotypes (usually to higher values in Icatu), what was mostly maintained at high temperatures, despite sucrose decline. In fact, these changes in total SS were closely associated with mannitol variations that represented up to 25% of total SS in WW plants at 25ºC, but raised to *ca*. 80% in both genotypes under single SWD (25ºC) or under maximum stress conditions (SWD-42ºC), especially in Icatu.

Conclusions & Perspectives:
Under SWD (25 and 42ºC), Icatu plants showed greater mannitol increases, reflecting a positive response since this molecule act as an osmoprotectant of membranes and proteins (stabilizing their structures) and as a ROS scavenger, also protecting photosynthetic apparatus, with a greater presence being associated with stress tolerance [2].

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Acknowledgments: Funding support by EU Horizon 2020 research and innovation program (GA No 727934, proj. BreedCAFS), and national funds from Fundação para a Ciência e a Tecnologia, through project PTDC/ASP-AGR/31257/2017, the Scientific Employment Stimulus-Individual Call (CEEC Individual)-2021.01107.CEECIND/CP1689/CT0001 (IM), the research units CEF (UIDB/00239/2020), GeoBioTec (UIDP/04035/2020), and associated laboratory TERRA (LA/P/0092/2020). Brazilian fellowships from CNPq to F.L. Partelli and F.M. DaMatta, and the FAPEMIG (project CRA-RED-00053-16, APQ01512-18), to F.M. DaMatta, are also greatly acknowledged.

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Leaf anatomical traits responsiveness to increased air [CO2] in *Coffea arabica* L. hybrid and its parental genotypes

Simões-Costa Maria C.*[1] (cristinasimoescosta@gmail.com), Sousa Vicelina*[2], Silva Maria J.[2, 3], Marques Isabel[2], Lidon Fernando C.[3], Ribeiro-Barros Ana I.[2, 3], Ramalho José C.[4]

[1] *Linking Landscape, Environment, Agriculture and Food, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [2] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Lab Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [3] *Centro de Geobiociências, Geoengenharias e Geotecnologias, FCT NOVA, Caparica, Portugal* ; [4] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Lab Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal, * these authors contributed equally to this work.*

Rationale:
Different tolerance potential has been reported among *Coffea arabica*L. genotypes under environmental stresses, with elevated air [CO2] playing a relevant role in the expression of plant acclimation ability [1]. Foliar traits are important for the success of plant acclimation to such environmental constraints in the context of climate changes [2]. Histochemical and anatomical analyses are valuable approaches to study the leaf lamina traits, with the potential to be used as biomarkers. Therefore, we study the foliar anatomical responses of *C. arabica* genotypes to elevated air [CO2].

Methods:
Plants from *C. arabica* L. *cvs*. Geisha 3 (G3), Marsellesa (Mar), and their Hybrid (Hy) were grown for 2 years under controlled environmental conditions (RH: 70%; irradiance: 700-800 µmol m-2 s-1; photoperiod: 12h; temperature: 25/20°C (day/night); air [CO2]: 400 (aCO2) or 700 (eCO2) µL CO2 L-1), under well-watered conditions. Quantitative analysis of microscopic leaf anatomical characteristics was performed in newly mature leaves to obtain: lamina thickness, the upper and lower cuticle and epidermis thickness, and the mesophyll thickness by measuring the palisade and spongy parenchyma tissues separately.

Results:
At elevated [CO2] no significant differences were observed between the three genotypes, while at a(CO2) the hybrid showed a significant thicker palisade parenchyma and thinner mesophyll. The e(CO2) was responsible for significant decreases of the upper and lower cuticle, as well as of the lower epidermis in all genotypes. Additionally eCO2promoted a significant increase of the palisade parenchyma in the G3 and Mar and of the mesophyll in Hy plants.

Conclusions & Perspectives:
The rise of air [CO2] altered some anatomical leaf traits. In this way, additional studies are needed to unveil their role in the potential plant acclimation to environmental limitations that are expected increase along the present century [3].

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Leaf anatomical traits responsiveness to warming in *Coffea arabica*L. *cv*. Geisha3 plants

Sousa Vicelina*[1] (vsousa@isa.ulisboa.pt), Simões-Costa Maria C.*[2], Silva Maria J.[1, 3], Marques Isabel[1], Lidon Fernando C.[3], Ribeiro-Barros Ana I.[1, 3], Ramalho José C.[4, 5]

[1] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Lab Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [2] *Linking Landscape, Environment, Agriculture and Food, Instituto Superior de Agronomia, Universidade de Lisboa, Lisbon, Portugal* ; [3] *Centro de Geobiociências, Geoengenharias e Geotecnologias, FCT NOVA, Caparica, Portugal* ; [4] *PlantStress & Biodiversity Lab., Centro Estudos Florestais, Lab Associado TERRA, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal* ; [5] *Centro de Geobiociências, Geoengenharias e Geotecnologias, FCT NOVA, Caparica, Portugal, * these authors contributed equally to this work.*

Rationale:
Different heat tolerance and acclimation potential has been reported for *C. arabica* genotypes [1]. Foliar traits are important for the success of plant acclimation to environmental constraints in the context of climate changes [2]. Histochemical and anatomical analysis are valuable approaches to study the leaf lamina traits, and their relation to the thermal acclimation. Therefore, we study the foliar anatomical responses of *cv*. Geisha3 plants to air temperature increase.

Methods:
Plants from *C. arabica cv.* Geisha 3 (G3) were grown for 2 years under controlled environmental conditions (RH: 70%; irradiance: 700-800 µmol m-2 s-1; photoperiod: 12h; temperature: 25/20°C (day/night); air [CO2] 400µL CO2 L-1, under well-watered conditions. Afterwards were submitted to a gradual temperature raise (up to 42/30ºC; 0.5ºC day-1) followed by a recovery period (25/20ºC) (Rec14) [2]. Quantitative analysis of microscopic leaf anatomical characteristics was performed in newly mature leaves.

Results:
The thickness of the upper and lower cuticles changed with air temperature, ranging from a minimum at 37°C (0.767/0.667 µm, respectively) to a maximum at 25°C (0.904 µm, upper) and 42°C (0.821 µm, lower), decreasing in Rec14 on upper cuticle. In general, the thickness of the upper and lower epidermis did not change significantly with increasing temperature, but maximum values were found in Rec14 (26.33/17.59 µm for upper and lower epidermis, respectively) that was significantly thicker than in control (23.65/15.27 µm). For the sponge parenchyma and mesophyll along temperature rise no significant differences were observed, while palisade parenchyma had a maximum at 31°C (54.18 µm). Leaf blade was thicker at Rec14 (247.37 µm) than in others air temperatures and control (231.40 µm).

Conclusions & Perspectives:
Complementary studies are needed to associate the temperature-dependent changes in different leaf traits and a possible plant acclimation ability to the imposed severe heat conditions [3].

Acknowledgments: Coffee plants were provided by Hervé Etienne (CIRAD-UMR DIADE, France) in the framework of the BreedCAFS project. Funding support by EU Horizon 2020 research and innovation program (GA No 727934, proj. BreedCAFS), and national funds of Fundação para a Ciência e a Tecnologia, I.P., Portugal, through the project PTDC/ASP-AGR/31257/2017, the contract DL57/2016/CP1382/CT0004 (VS), the Scientific Employment Stimulus-Individual Call (CEEC Individual)-2021.01107.CEECIND/CP1689/CT0001 (IM), the research units CEF (UIDB/00239/2020), GeoBioTec (UIDP/04035/2020), LEAF (UIDB/04129/2020), and the associated laboratory TERRA (LA/P/0092/2020).

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Dry matter accumulation in berries of two *Coffea canephora* genotypes during berry expansion and maturation

Salvador Henzo[1, 2] (henzosalvador@hotmail.com), Partelli Fábio[2], Rakocevic Miroslava[2], Semedo José[3], Ramalho José[4]

[1] *Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [2] *Tropical Agriculture Post graduate Program, Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [3] *Biotechnology and Genetic Resources Research Unit, national institute of agricultural and veterinary research, Lisbon, Portugal* ; [4] *3Plant Stress & Biodiversity Lab, Forest Research Center, School of Agriculture University of Lisbon, Lisbon, Portugal*

Rationale:
The accumulation of dry matter (DM) over time, especially in berries, differs among the coffee genotypes [1].The knowledge about the processes of DM accumulation that occur in the berries is of great importance to obtain a high productivity materials.

Methods:
Two Conilon genotypes were used. The collection of coffee berries began at the 33rd week after flowering (WAF), and was performed every 14 days, until the 49th WAF. The berry drying was performed in oven with a forced circulation at 50 °C, until reaching a constant mass.

Results:
The highest rates of DM accumulation were observed during the transient period between the end of berry expansion and the beginning of berry maturation (33rd – 43rdWAF). The berry DM accumulation from berry expansion to full maturation passed through one phase of rapid growth in linear behavior and a second phase of stabilized DM accumulation [2].

Conclusions & Perspectives:
The trend of curves of accumulation was similar for the two coffee genotypes, adjusting to the quadratic regression model. Both genotypes seamed interesting for the future breeding processes, due to their high berry weight.

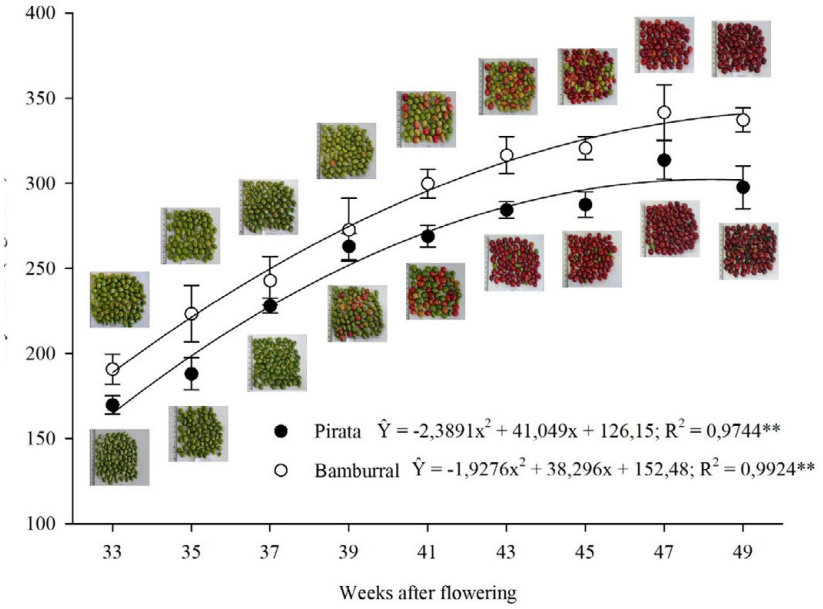

Figure 1. Accumulation of dry matter in berries of two genotypes of Coffea canephora over nine moments of berry expansion and maturation.

References:

1. Partelli et al, Revista Brasileira de Ciência do Solo, 2014, 214-222.
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Nitrogen accumulation in berries of two genotypes of *Coffea canephora* during berry expansion and ripening

Salvador Henzo[1, 2] (henzosalvador@hotmail.com), Partelli Fábio[2], Rakocevic Miroslava[2], Semedo José[3], Ramalho José[4]

[1] *Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [2] *Tropical Agriculture Post graduate Program, Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [3] *Biotechnology and Genetic Resources Research Unit, National Institute of Agricultural and Veterinary Research, Lisbon, Portugal* ; [4] *Plant Stress & Biodiversity Lab, Forest Research Center, School of Agriculture University of Lisbon, Lisbon, Portugal*

Rationale:
Requirement of coffee crops, the mineral fertilization is a extremely important soil management in coffee cultivation[1]. However, there are only few reports about the Conilon coffee plant necessity of each mineral nutrient throughout vegetative and reproductive cycles, making difficult the proper crop management.

Methods:
Two *Coffea canephora* genotypes were used. The berry collection began in the 33rd week after flowering (WAF), and was performed every 14 days, until the 49th WAF. The berry drying was performed in an oven with a forced circulation at 50 °C. The N was determined by methodology of Silva (2009)[2].

Results:
Acumulation of N in the coffee berries showed the similar trend for both genotypes, with higher rates of accumulation initially, followed by a period of stabilization. The N has greater role in vegetative growth of the coffee trees, but it also has essential functions in the berry expansion and ripening [3].

Conclusions & Perspectives:
Berry N accumulation curves had similar trends in two Conilon coffee genotypes, adjusted to the quadratic regression. Mineral fertilization with N has been shown to be considerably important even in the berry ripening phase.

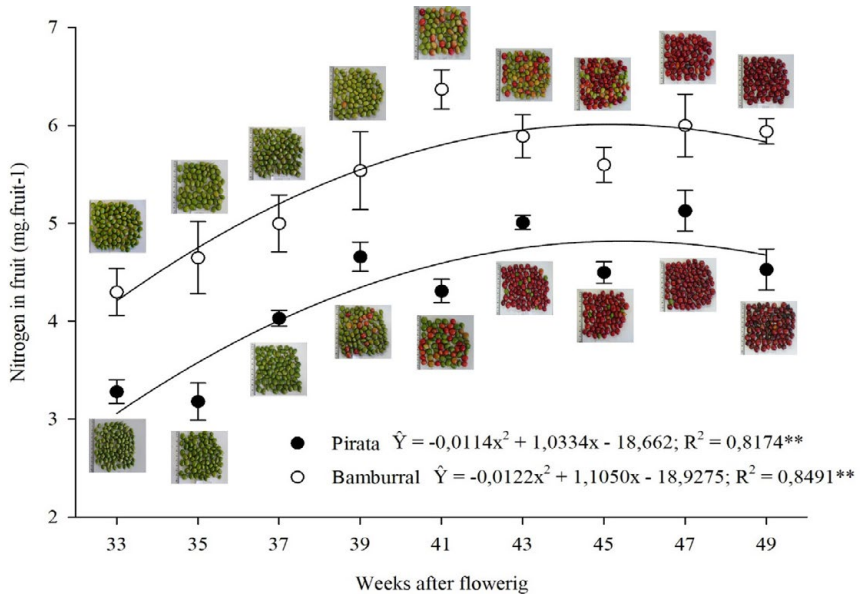

Figure 1. Nitrogen accumulation in berries of two Coffea canephora genotypes harvested during berry expansion and ripening.

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Genetic-environment interactions and climatic variable effects on bean physical characteristics and chemical composition of *Coffea arabica* F1- hybrids in Vietnam

Sarzynski Thuan[1] (thuan.sarzynski@ecomtrading.com), Bertrand Benoit[2], Rigal Clement[3], marraccini Pierre[4], Vaast Philippe[5], Nguyen Chang[6], Nguyen Hung[6], Nguyen Hai[7], Ngoc Quyen[7], Navarini Luciano[8], Etienne Herve[2]

[1] *DIADE, CIRAD, Ho chi minh, Vietnam* ; [2] *DIADE, CIRAD, Montpellier, France* ; [3] *Absys, CIRAD, Hanoi, Vietnam* ; [4] *DIADE, CIRAD, Kampala, Uganda* ; [5] *Eco&Sol, CIRAD, Cali, Colombia* ; [6] *NOMAFSI, Son La, Vietnam* ; [7] *NOMAFSI, Phu Tho, Vietnam* ; [8] *illy cafe, Milan, Italy*

Rationale:
Coffee bean chemical compounds and quality depends on genetic factors which opens opportunities to breed genotypes for better quality. F1-hybrids developed by CIRAD and ECOM in the last decades have shown better bean physical characteristics and better sensory quality. The genetic factors interact with environmental ones, and hence this interaction also has an impact on coffee chemical composition and beverage quality. Climate change is predicted to decrease globally the areas suitable for coffee cultivation, and to create new frontiers for coffee management. However, the effects of climate change on coffee quality in these frontier areas with suboptimal conditions are still largely unknown.

Methods:
The effects of the environment and genotype in the coffee bean chemical composition were studied using nine trials covering an altitudinal gradient [600–1100 m above sea level (m.a.s.l.)] with three genotypes of *Coffea arabica* in the northwest mountainous region of Vietnam. The impacts of the climatic conditions on bean physical characteristics and chemical composition were assessed.

Results:
We showed that the environment had a significant effect on the bean density and on all bean chemical compounds. The environment effect was stronger than the genotype and genotype-environment interaction effects for cafestol, kahweol, arachidic (C20:0), behenic acid (C22:0), 2,3-butanediol, 2-methyl-2-buten-1-ol, benzaldehyde, benzene ethanol, butyrolactone, decane, dodecane, ethanol, pentanoic acid, and phenylacetaldehyde bean content. A 2 °C increase in temperature had more influence on bean chemical compounds than a 100 mm increase in soil water content. Temperature was positively correlated with lipids and volatile compounds. With an innovative method using iterative moving averages, we showed that correlation of temperature, vapor pressure deficit (VPD) and rainfall with lipids and volatiles was higher between the 10th and 20th weeks after flowering highlighting this period as crucial for the synthesis of these chemicals. Genotype specific responses were evidenced and could be considered in future breeding programs to maintain coffee beverage quality in the midst of climate change.

Conclusions & Perspectives:
This first study of the effect of the genotype–environment interactions on chemical compounds enhances our understanding of the sensitivity of coffee quality to genotype environment interactions during bean development. This work addresses the growing concern of the effect of climate change on specialty crops and more specifically arabica coffee.

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Inheritance of resistance to *Pseudomonas coronafaciens* pv. *garcae* on Ethiopian wild Arabica coffee

Sera Gustavo H.[1] (gustavosera@idr.pr.gov.br), Carvalho Filipe G.[1, 2], Rodrigues Lucas M. R.[3], Guerreiro-Filho Oliveiro[3], Destefano Suzete A. L.[4], Pereira Carlos T. M.[1, 2], Ariyoshi Caroline[1, 5], Shigueoka Luciana H.[1, 6], Fonseca Inês C. de B.[2]

[1] *Plant Breeding, IDR-Paraná, Londrina, Paraná, Brazil* ; [2] *Agronomy, UEL, Londrina, Paraná, Brazil* ; [3] *Coffee Center Alcides Carvalho, IAC, Campinas, São Paulo, Brazil* ; [4] *Plant Pathology, Instituto Biológico, Campinas, São Paulo, Brazil* ; [5] *INCT Café, Lavras, MG, Brazil* ; [6] *Consórcio Pesquisa Café, Brasília, DF, Brazil*

Rationale:
The bacterial-halo-blight (BHB) is an important disease caused by the bacterium *Pseudomonas coronafaciens* pv. *garcae*, responsible for significant losses in the *Coffea arabica* crop. In *Coffea* spp., there are resistance sources to BHB, but there are few cultivars that are highly resistant to this bacterium. Recently, resistance to *P. coronafaciens* pv. *garcae* is associated with a major specific gene called *Pga* [1]. The objective of this study was to characterize the inheritance of resistance to *P. coronafaciens* pv. *garcae* from the wild accession of Ethiopia E287.

Methods:
To study the inheritance of resistance, the accession E287 was used as a resistant parent (P1) and the Sarchimor Mococa genotype as a susceptible (P2). These were used to obtain the F1(P1 x P2), F2 (F1 x F1) generations and backcrosses (F1 x P1; F1 x P2) with both parents. The resistance evaluation was carried out in 20, 20, 15, 155, 40 and 40 seedlings, respectively, of P1, P2, F1, F2, F1 x P1 and F1 x P2. Young leaves of all seedlings were inoculated by the abrasion method [2] with the bacteria strain IBSBF 1197 (highly aggressive, originating from the Campinas, SP, Brazil, isolated in 1995). After inoculations, the plants were kept in greenhouse conditions, with humidity controlled to be kept above 80%. Severity was evaluated 30 days after inoculations, using a scale of 0 to 5 points [2]. Plants with a score of 0, those without signs of colonization by the bacteria, were classified as resistant (R) and the others, even with a low rate of infection in the wounds, as susceptible (S). The data obtained from the evaluations of all generations were submitted to analysis by the chi-square test (χ^2), for different segregation proportions, aiming at estimating the number of genes involved in the expression of plant resistance to the disease.

Results:
All plants from the self-pollination of the P1 and P2 were, respectively, classified as R and S. All plants of the F1 and F1 x P1 generations were classified as R. In the F1 x P2 generation, 21 plants (52.5%) were classified as R and 19 (47.5%) as S. In the F2 generation, 33 plants (21.29%) were classified as S and 122 plants (78.71%) were classified as R. The results of our study suggest that the resistance to BHB of E287 is of dominant character and the allelic interaction is of complete dominance, probably due to the *Pga* gene described in a previous study [1].

Conclusions & Perspectives:
We conclude that the inheritance of resistance to *P. coronafaciens* pv. *garcae* from the wild accession of Ethiopia E287 is also controlled by a major dominant gene of qualitative character and complete dominance.

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Viability of deficit irrigation pre-exposure in adapting Robusta coffee to drought stress

Sseremba Godfrey[1, 2] (gsseremba16@gmail.com), Tongoona Pangirayi Bernard[2], Musoli Pascal[1], Eleblu John Savior Yaw[2], Melomey Leander Dede[2], Bitalo Daphne Nyachaki[1], Atwijukire Evans[1], Mulindwa Joseph[1], Aryatwijuka Naome[1, 3], Muhumuza Edgar[1], Kobusinge Judith[1], Magambo Betty[1], Kagezi Godfrey Hubby[1], Danquah Eric Yirenkyi[2], Kizito Elizabeth Balyejusa[3], Kyalo Gerald[4], Iyamulemye Emmanuel[4], Arinaitwe Geofrey[1]

[1] *National Coffee Research Institute, National Agricultural Research Organisation, P.O. Box 185, Mukono, Uganda* ; [2] *West Africa Centre for Crop Improvement, University of Ghana Legon, PMB LG30, Accra, Ghana* ; [3] *Department of Agriculture, Faculty of Agricultural Science, Uganda Christian University, P.O. Box 4, Mukono, Uganda* ; [4] *Technology Development, Uganda Coffee Development Authority, P.O. Box 7267, Kampala, Uganda*

Rationale:
Coffea canephora has high but inadequately exploited genetic diversity. This diversity if well exploited can sustain coffee productivity amidst climate change effects. Drought and heat stress are major global threats to coffee productivity, quality, and tradable volumes. It is not well understood if there is selectable variation for drought stress tolerance in Robusta coffee half-sibs as a result of watering deficit pre-exposure at germination stage.

Methods:
Half-sib seeds from selected commercial clones (KR5, KR6, KR7) and a pipeline clone X1 were primed with deficit watering at two growth stages followed by recovery and later evaluated for tolerance to watering deficit stress in three different temperature environments by estimation of plant growth and wilt parameters.

Results:
Overall, the KR7 family performed the best in terms of number of individuals excelling for tolerance to deficit watering. In order of decreasing tolerance, 10 most promising individuals for drought and heat tolerance were identified as; 14.KR7.2, 25.X1.1, 35.KR5.5, 36.KR5.6, 41.KR7.5, 46.KR6.4, 47.KR6.5, 291. X1.3, 318.X1.3 and 15.KR7.3.

Conclusion & Perspectives:
This is a first prospect into potential of *C.canephora* half-sibs' diversity as an unbound source of genetic variation for abiotic stress tolerance breeding.

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Liberica coffee exploration: a promising coffee for the future?

Sunarharum Wenny Bekti[1] (wbsunarharum@ub.ac.id), Mahatmanto Tunjung[1], Hakim Luchman[2], Da Lourdes Agnes[1], Barlian Inessa Salsabila[1], Kartika Annisa Aurora[1]

[1] *Department of Food Science and Biotechnology, Universitas Brawijaya, Malang, East Java, Indonesia* ; [2] *Department of Biology, Universitas Brawijaya, Malang, East Java, Indonesia*

Rationale:
Global coffee production is declining, mostly due to the environmental pressures that arise from climate change. This decline has led to a significant increase in coffee prices, particularly arabica (*Coffea arabica*) and robusta (*Coffea canephora*), in the last decade[1] and has prompted efforts to sought for alternative species such as *Coffea liberica*[2]. From an ecological perspective, liberica coffee plants are attractive because they are more resistant to climate change and can support agroforestry systems[3]. In Indonesia, this coffee is cultivated in several areas, including the Ijen Banyuwangi Geopark Area, East Java, Indonesia. We seek to explore the potential of liberica coffee for supporting the production of high quality coffee as an alternative to arabica and robusta.

Methods:
This study explored liberica coffee farms in the Banyuwangi Geopark Area, East Java, through field observation and laboratory analyses. Green liberica coffee beans (naturally processed, harvested in 2021) from six farms were sampled, medium-roasted, and analysed to determine their physical and chemical properties. The sensory profiles of the roasted beans were analysed using the Specialty Coffee Association (SCA) cupping test and the descriptive method.

Results:
Liberica coffee farms in Banyuwangi employ an inter-cropping system (non mono-culture) where coffee plants are planted under the shade of trees and shrubs so that they have fairly high biodiversity. The liberica coffee plants are characterised by wide leaves, with large, thick, and fleshy cherries. The green beans have an oval almond-like shape. Roasted liberica coffee beans contain ~2% moisture, 12% fat, 13% protein, 68% carbohydrates, 1.2% caffeine, and have a pH of 5. The highest cupping score was 77.5, slighlty below the score for speciatly coffee. However, it had remarkably complex notes: smoky, roasty, nutty, chocolate, caramel, spicy, dried fruit, jack fruit, black tea, and bitter.

Conclusion & Perspectives:
Liberica coffee has the potential to be developed not only because of its higher resistance to climate change but also because of its unique properties. Although liberica coffee might not as flavorful as that of arabica, its quality can be improved to meet the standards of specialty coffee. We are currently developing processing techniques to unleash the unique sensory profiles of liberica coffee. We believe that liberica coffee holds promise for the future of the coffee industry. Further research and collaboration will be crucial to unlock its full potential.

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Estimation of carbon stored in plant biomass and quantification of macronutrient contents (N, P, K, Ca, Mg) in plant tissue in coffee plantations in Cerrado Mineiro

Teixeira Aldir (aldir.teixeira@illy.com)

Experimental Agrícola do Brasil, São Paulo, SP, Brazil

Rationale:
The objective was to evaluate the stocks of carbon and macronutrients (N, P, K, Ca and Mg) in the biomass of coffee plants at different stages of development in Minas Gerais.
Methods:
Plants were uprooted for later separation and individual quantification of the biomass. Samples were dried in an oven to obtain the dry mass content and submitted for determination of C, N, P, K, Ca, Mg contents. Based on the results of dry plant material mass and element content, the stocks of each element in the biomass were calculated.
Results:
The results demonstrated that the accumulation of plant biomass occurred in a logarithmic way, with intensive growth in the first years of cultivation and stabilization after 10 years. C is the most abundant element in plant biomass, approximately 50% of the total dry mass. Nutrients presented concentrations following the order N>K>Ca>Mg>P. Most nutrients, especially those mobile ones in the plant, were found in higher concentrations in the most active compartments, such as leaves and fruits.
Conclusions & Perspectives:
One must highlight the importance of considering studies aimed at quantifying the C levels and nutrients in plant biomass, since the information generated allows estimating the ability of coffee plants to temporarily immobilize CO2 in the form of biomass and consequently contribute to the environment. In addition, quantifying nutrients allows for identifying the amount of nutrients exported annually via fruit, helping to manage fertility in coffee production areas.

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Which genetic diversity was brought to Vietnamese Robusta coffee (*Coffea canephora*)?

Vi Tram[1,2] (vbt576@gmail.com), Cubry Philippe[1], Marraccini Pierre[1,3], Dinh Thi Tieu Oanh[4], Phan Viet Ha[4], Zhang Dapeng[5], Stoffelen Piet[6], Vigouroux Yves[1], Poncet Valérie[1], Khong Ngan Giang[2]

[1] *DIADE, Univ Montpellier, CIRAD, IRD, Montpellier, France* ; [2] *AGI, Hanoi, Vietnam* ; [3] *CIRAD, UMR DIADE, Montpellier, France* ; [4] *WASI, Buon Ma Thuot, Vietnam* ; [5] *Sustainable Perennial Crops Laboratory, USDA-ARS, Beltsville, Maryland, USA* ; [6] *Meise Botanic Garden, Meise, Belgium*

Rationale:
As a consequence of climate change, Vietnam, the world's largest Robusta producer, is facing the risk of observing yield anomalies variation in Robusta production because of its sensitivity to weather in the producing regions (Dinh et al., 2022). To develop varieties that are better adapted to climate change, it is important to understand the genetic makeup and diversity of *Coffea canephora* cultivated in Vietnam. Robusta accessions from the WASI germplasm bank (in Dak Lak province) were collected for genomic evaluation.

Methods:
A total of 126 accessions were collected in WASI including 10 elite accessions (previously analyzed in Vi et al. 2023). A collection of African wild accessions of *C. canephora*, covering the wild diversity previously identified, were included as genetic references. 261 SNPs, selected from a 8.5K SNP array (Mérot-L'Anthoëne et al., 2019), were used to analyze the genetic diversity of the Vietnamese collection in relation to the wild African groups. A core set of representative individuals were selected to minimize genetic redundancy and maximize allelic diversity. Admixture segments of these individuals were further assigned at the chromosome level using whole-genome sequencing data, by a local ancestry inference method adapted in *C. canephora* (Vi et al., 2023).

Results:
Most of the Vietnamese genotypes were closely-related with accessions originating from the Democratic Republic of the Congo (DRC), corresponding to groups E and R (Mérot-L'Anthoene et al., 2019), at high membership probability (> 90%). Few varieties including one elite accession presented introgressions, at different levels, from group A and G (Cameroon-Gabon and Angola groups, respectively), or group O (Uganda), or D (Guinean group). Contribution of each African source at the chromosome level, on the sequenced individuals of the core set, led to the identification of recent backcrosses and multi-way admixtures.

Conclusions & Perspectives:
The diffusion and hybridization of *C. canephora* in Vietnam were from multiple African sources of different geographical origins, but with a Congolese genomic background. Such an approach should contribute to the selection of elite parental genotypes necessary to further launch new Robusta breeding programs.

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Coffee (*Coffea arabica* L.) Breeding in Ethiopia: Achievements, Current status and Future Prospects

Waya Lemi Beksisa (lbeksisa@gmail.com), Benti Tadesse, Alemayehu Desalegn, Marga Dawit, Tefera Fekadu, Zakir Mohammedsani, Adissu Melaku, Ayano Ashenafi, Getaneh Admikew, Kidanu Mabrate

Coffee Breeding, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia

Coffee is a perennial crop that belongs to the genus Coffea in the Rubiaceae family. Among 124 species in the genus Coffea, Coffea arabica L is the only self -pollinated tetraploid species while other species are diploid and self-incompatible. Ethiopia is the center of origin and diversity for Arabica coffee. The country is also endowed with ideal climatic and soil conditions, providing immense possibilities to improve the crop for desirable traits such as yield, quality and other traits of agronomic more than any other country in the world. In Ethiopia, comprehensive coffee breeding program was started after the outbreak of coffee berry disease (CBD) in 1971 with the main objectives of developing cultivars that combine high yield, disease resistance and good quality. To achieve the desired goal, different activities and efforts were made; among which coffee genetic resource collection, characterization, selection and heterotic hybridization were the major ones. Up to date, considerable successes have been recorded in coffee breeding program such as; collecting and conserving more than 7000 germplasm accessions, generating basic information on the genetics aspects of agronomic traits and development of 44 improved varieties of which nine are F1 hybrids. Despite remarkable achievements made in coffee breeding program, there are also still research gabs that have not been attained in the coffee breeding program which require to be addressed to ensure sustainability in coffee improvement program. Therefore, developing very high quality cultivars through systematic and effective selection and breeding program, collection of coffee genetic resources from unaddressed areas, an application of modern plant breeding methods and breeding for stress tolerance, among others, would be the main focus areas of future coffee breeding program.

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AHERNT: The first commercial release yellow Arabica variety in Indonesia resulted from participatory local selection

Wibowo Ari[1] (ariwibowo.iccri@gmail.com), Suganda Dudung Ahmad[2], Yusianto Yusianto[3], Setyawan Bayu[1], Rahayu Dwi Suci[4], Hartatri Diany Faila Sophia[5], Widiyanto Rais[4], Romadhoni Fraizal[1], Dayawiguna Dani[2], Bunyamin Roni[2], Subroto Gatot[6], Sumirat Ucu[1]

[1] *Plant Breeding and Biotechnology, Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia* ; [2] *Dinas Perkebunan Provinsi Jawa Barat, West Java, Indonesia* ; [3] *Post Harvest, Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia* ; [4] *Plant Protection, Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia* ; [5] *Socio-economic, Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia* ; [6] *Balai Besar Perbenihan dan Proteksi Tanaman Perkebunan, Surabaya, Indonesia*

Rationale:
Participatory breeding in Indonesian coffee have been done intensively since the first success of commercially release in 2006 due to accommodate and appreciate local (farmers) selection. This method giving the power of faster output compared to designed ones which taking time mostly decades for desired variety, especially if the target is multiple traits. Our work was the first successfully applied this method combining exotic yellow color of cherry with superior yield, and resistance to Leaf Rust Disease (CLR) and Coffee Berry Borer (CBB). This variety of AHERNT was finally accepted and granted for commercial release in Indonesia since mid of 2022 after two years examined by national council for variety release.

Methods:
The adaptability and stability of AHERNT was observed by GGE Biplot method for three consecutive years from single farm having three different consecutive planting years, while annual yield capacity was observed from four different farms. Resistance to CLR was following the method of OIRSA (2013) *cit*. de Melo Virginio Filho (2015), and resistance to CBB was according to Romero & Cortina-Guerrero (2004) and Sera et al. (2010) which re-developed by Sumirat (2012). Resistance to root lession nematode *Pratylenchus coffeae* was according to Wiryadiputra *et al*. (2004) & Hulupi *et al*. (2007) with some modifications. The assesment of cup quality was accordingly to the SCAA system.

Results:
The AHERNT was found more adaptive and stable compared to Sigarar Utang as control of Indonesian commercial variety with potential annual yield of 2,79 ton/ha green beans in average. This variety was also more resistant to CLR and CBB, while having the same resistance level to nematode compared to the control. Higher cupping score than control was completing the superior desired traits of this variety.

Conclusions & Perspectives:
This result suggested the promising of participatory method for accelerating release of superior variety with multiple targeted traits. Moreover, impact of climate change to the coffee production should be answered as fast as possible. Distribution of the seeds is expected commnencing in next two years mainly in surrounding region where this trial conducted.

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SNP Genotyping of the First Yellow Arabica Coffee Variety 'AHERNT' Selected Through Participatory Breeding in Indonesia

Sumirat Ucu[1] (ucu_sumirat@yahoo.com), Wibowo Ari[1], Romadhoni Fraizal[1], Solano-Sánchez William[2], Zhang Dapeng[3]

[1] *Indonesian Coffee and Cocoa Research Institute (ICCRI), Jember, East Java, Indonesia* ; [2] *Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Cartago, Costa Rica* ; [3] *USDA-ARS, Sustainable Perennial Crops Laboratory, Beltsville, MD, USA*

Rationale:
Farmer participatory breeding has been commonly adopted in Indonesia as an effective coffee breeding method in the last 20 years, resulting the release of numerous new varieties. However, so far none of those released varieties have been comprehensively assessed in terms of genetic identity using molecular markers. Here we report our first application of SNP genotyping technology on a new Arabica variety 'AHERNT', a variety with a distinguished genetic profile and unique yellow cherry, selected through farmer participatory breeding method.

Methods:
This AHERNT variety is selected locally by farmers in West Java province with introduced germplasm, but the source of origin is unknown. Leave samples were taken from several farms where the variety was originally developed. The sampled trees have similar morphological characteristics, such as dwarf type, green flush, rounded and dark green leaves, eliptical immature green cherry and rounded mature yellow cherry. The low-density SNP panel including 96 markers (1) was used to genotype the AHERNT variety. The SNP data was analyzed using method as previous described (1).

Results:
Based on the genotyping result, we compared the SNP profiles of AHERNT with 30 reference arabica varieties. The result of direct multi-locus comparison found no matching varieties. Principle Coordination and UPGMA dendrogram showed that samples of AHERNT formed an independent cluster, demonstrating the unique genetic background of AHERNT. The result of multivariant analysis was further supported by STRUCTURE analysis using admixture model. Genetic profiles of sampled trees from different farms are consistent and comparable in AHERNT. However, intra-varietal variation was also detected in AHERNT, showing a moderate segregation in this variety.

Conclusions & Perspectives:
Our result confirmed that AHERNT has a unique genetic profile that differs from the reference varieties. Its genetic profile is consistent across different farms. However, the observed intra-varietal variation suggests that AHERNT is an introgressed variety with residue segregation. It can be said that AHERNT is a type of composite variety. This kind of variety is expected to have better resilience to the impact of climate change, as well as resistance to pests and disease since the variety comprised of many mixed genotypes, which can increase the functional diversity on farms and provide a more sustainable deployment of new Arabica coffee varieties. The result has broad implication in downstream application of SNP genotyping to support coffee breeding and coffee production in Indonesia.

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Selection of coffee varieties resistant to *Fusarium stilboides*

Alwora Getrude[1] (alworahgetrude@gmail.com), Ondura Ogendo Joshua[2], Mafurah Joseph[2], Gichuru Elijah[1], Miano Douglas[3], Otieno Oliver[3]

[1] *Plant Pathology, KALRO-Coffee Research Institute, Ruiru, Kiambu, Kenya*; [2] *Crops Horticulture and Soils, Egerton University, Egerton, Nakuru, Kenya* ; [3] *Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya*

Rationale:
Fusarium stilboides Steyaert causes Fusarium Bark Disease in Arabica coffee, associated with yield losses and tree death in coffee-growing countries in East Africa. A lack of resistant varieties or effective chemical control methods greatly hinders disease management. This study investigated the response of four coffee cultivars to *F. stilboides*.
Methods:
Fifteen (15) seedlings of each of the four coffee cultivars were inoculated with *F. stilboides* at a concentration of 10^6 using the injection method with a 0.5 mm syringe. The inoculated seedlings were incubated at 24±2 ° C for 105 days. The plants were watered regularly as necessary while symptom development was observed and assessed weekly. Disease severity was evaluated using a modified scale of 0-4, while incidence was scored as a percentage of infected seedlings. The experiment was laid out in RCBD of 4 replications for two seasons.
Results:
Coffee seedlings inoculated with *F. stilboides* developed symptoms such as wilting, stunted growth and defoliation. In the first season, Robusta had the lowest severity levels compared to other varieties. In the second season, Batian and Ruiru 11 had pronounced severity when compared to other varieties. The TN002B (I) isolate was highly virulent as compared to other isolates.
Conclusions & Perspectives:
The variation in response to disease infection exhibited by the four cultivars presents a key input in breeding programs for resistance to *F. stilboides.*

Key words: Fusarium Bark Disease - Inoculation - Resistance - Pathogenicity - Severity.

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In vitro efficacy evaluation of ViCare® against coffee berry disease and coffee leaf rust

Alwora Getrude (alworahgetrude@gmail.com), Gichuru Elijah, Malaka Samuel, Msenya Happiness

Plant Pathology, KALRO-Coffee Research Institute, Ruiru, Kiambu, Kenya

Rationale:
Arabica coffee supports the livelihood of over half a million smallholder farmers in Kenya. However, Coffee leaf rust (CLR) and Coffee berry disease (CBD) have majorly affected its production. This study assessed the efficacy of ViCare®, a probiotic foliar containing phosphorus, micronutrients, natural oils, polyelectrolytes, and organic acids agaist CLR) se CBD).

Methods:
The treatments were 10 rates ofViCcare® (0.5 to 5.0 L/Ha), 3 standards Copper Oxychloride 500g/L at 7.7 Kg/Ha, Pyraclostrobin 250 g/L at 0.4 L/Ha and Mono+Di Potassium phosphite at 6.0 L/Ha, and untreated control. CBD plating media was prepared by mixing 49.14 grams of dehydrated Potato Dextrose Agar with 1.26 litres of distilled water and vigorously shaking to mix and autoclaved at 15 lbs pressure (121^{o}C) for 15 minutes and allowed to cool to about 55 ^{o}C to add one millilitre of Tetracycline . One ml of the treatments were added to each plate. Three isolates from Bungoma, Nandi and Kiambu Counties were tested. Aseptically 10mm disc was transferred to the centre of each plated PDA and incubated at 22 C. For CLR, three coffee leaves with active CLR lesions were placed on paper towel in each box replicated three times. One ml of each treatment was applied per box using an atomizer. The leaves were incubated at room temperature and data was collected every 24 hrs. The sporulation percentage and size were recorded daily after 48 hors,. using a scale of 1 (no spores)-5 (heavy spores). For detached uredospore, the lesions were wiped using wet cotton wool. Analysis of variance was done by Proc Glm, and the means separated by Fisher's Least Significant Difference (LSD) at a 95% confidence level using SAS software (SAS, 2002).

Results:
ViCare® was effective against CLR by 15% and 38.8% in seasons one and two, respectively, compared to untreated coffee plants. It was effective against CBD by 8.3% and 35.9% in seasons one and two, respectivel. Tthe application of 3.5 – 5 L/ha of ViCare® was effective agains CBD , although a lower quantity of 0.4 L/ha of the standard product, Cabrio 250 EC, was effective too. Also, applying 3.5 L/ha of ViCare® effectively controlled CLR.

Conclusions & Perspectives:
ViCare® was effective against CLR by 15% and 38.8% in seasons one and two, respectively compared to the control of untreated. It was also effective against CBD by 8.3% and 35.9% in seasons one and two; application of 3.5 – 5 L/ha of ViCare® was effective against CBD although a lower quantity of 0.4 L/ha of the standard product, Cabrio 250 EC was effective too; a standard constant application of 3.5 L/ha of ViCare® controlled CLR.

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Screening of Arabica coffee germplasm to coffee leaf rust (*Hemileia vastatrix*) at TaCRI, Lyamungu, Tanzania

Aman Nuhu (nuhu.aman@tacri.or.tz), Mwaipopo Rehema, Mtenga Damian, Kilambo Deusdedith

Crop Improvement Research Programme, Tanzania Coffee Research Institute, Moshi, Tanzania

Rationale:
Coffee leaf rust (CLR) caused by *Hemileia vastatrix* Berk. et Br. is among the most devastating diseases in coffee worldwide. In the 1960s, differet Aarabica coffee cultivars were collected and planted at TaCRI, Lyamungu, as germplasm materials. However, the level of resistance of sese germpasms to CLR under field conditions is not well known. Therefore, this study aimed to identify accessions shoving resistance under natural disease infection for genetic resource conservation and sustainable utilization.

Methods:
Sixteen cultivars of Arabica coffee were assessed for CLR under natural infection during March and July 2022 in a complete randomized block design with six replications. The disease severity followed a scale of 1 to 6013)inat which 1-2.4 was considered resistant, 2.5-3.4 moderately resistant, 3.5-4.4 tolerant, 4.5-5.4 moderately susceptible, and 5.5-6 susceptible. Data collected were subjected to GENSTAT Software Version 16 to generate means, variance, standard error, and coefficient of variation. Means were separated using Tukey's HSD at $p \leq 0.05$.

Results:
There were highly significant differences ($p \leq 0.01$) among the 16 Arabica coffee cultivars, at which I5, AC98, and R3 were observed to have scores of 4.06, 4.21, and 4.44 respectively, qualifying as tolerant at field conditions. N218, K1 363, N100, N205, N39, KP683, M95, N197, M197, I 235, and R11 were observed to have mean scores of 4.67, 4.89, 4.96, 5.00, 5.06, 5.18, 5.24, 5.28, 5.33, 5.41, and 5.43 respectively (moderately susceptible), while N5, KP532, and N110 had a disease score of 5.47, 5.53, and 5.70 respectively (high susceptibityle).

Conclusions & Perspectives:
The screened cultivars which are field-tolerant to CLR namely I5, AC98, and R3 can be used as female parents to be crossed with exotic male parents of known desirable traits, including resistance to the particular disease. However, more evaluation has to be done using inoculum, to establish their genetic diversity, cup quality test, and agronomical performances.

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Development and evaluation of mass trapping technology for Shot hole borer, *Xylosandrus compactus* (Coleoptera: Curculionidae) infesting coffee: A Potential IPM Strategy

Amsalingam Roobakkumar[1] (roobakkumar@gmail.com), Madhihalli Shanmukhappa Uma[1], Peketi Krishna Reddy[1], Kilannaparambil Tintumol[1], Halemane Ganesharao Seetharama[1], Nayani Surya Prakash Rao[2]

[1] *Division of Entomology, Central Coffee Research Institute, Coffee Board, Chikkamagaluru, Karnataka, India* ; [2] *Plant Breeding & Genetics, Central Coffee Research Institute, Coffee Board, Chikkamagaluru, Karnataka, India*

Rationale:
The Shot hole borer (SHB) is an emerging pest of Robusta coffee in India. The severe infestation of this pest leads to crop loss as it damages the new and succulent branches of coffee plants. Though the recommended measures are effective, they are not economically feasible for the majority of small growers because they require a large workforce. Traps baited with chemical attractants are becoming more popular in pest management, and if a strong attractant is available, mass trapping is one of the finest IPM tactics. Hence, the current study was conducted in order to identify an effective attractant for the management of SHB.

Methods:
The relative attractiveness of several common attractants and the influence of their concentration were evaluated in the field against SHB using Broca traps. Each treatment was replicated 5 times. To avoid experimental site error, all replications were rotated clockwise once a week. Trapped insects were collected at weekly intervals and differences between treatments were studied using analysis of variance and the means were separated by Duncan's multiple range test.

Results:
The initial trapping studies revealed that significant differences were observed in the mean number of adults captured among the tested attractants. Traps baited with absolute ethanol significantly attracted a greater number of adults (10.35 beetles/trap/week) compared to other attractants like coffee twig extracts, distillery ethanol, and ethanol methanol combinations. Based on the preliminary results, multi-location field studies were conducted in different coffee-growing regions of Karnataka. The number of beetles trapped varied in different places, but the mean number of beetles trapped revealed, 50% absolute ethanol-baited traps captured the highest number of beetles (27.50beetles/trap/week).

Conclusions & Perspectives:
Based on the current research findings, 50% absolute ethanol can be deployed as an effective attractant for SHB since it delivers the most consistent SHB captures. This mass trapping is efficient and environmentally safe technology, which can be undoubtedly incorporated as an IPM component f borer management.

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Could genes allocated to S_H3 loci contribute to other resistance factors?

Angelo Paula C S[1] (paula.angelo@embrapa.br), Yamagishi Michel[2], Silva Angelita G.[3], Ponce Talita P.[3], Ariyoshi Caroline[3], Shigueoka Luciana H.[3], Arantes Tiago[4], Gasparini Ana K.[5], Sera Gustavo H.[6], Pereira Luiz F.P.[1], Caixeta Eveline T.[7]

[1] *Embrapa Coffee/IDR-Paraná, Londrina, PR, Brazil* ; [2] *Embrapa Informática na Agricultura, Campinas, SP, Brazil* ; [3] *IDR-Paraná/Universidade Estadual de Londrina (Post-Grad Student), Londrina, PR, Brazil* ; [4] *IDR-Paraná/Universidade Estadual de Londrina (Undergrad Student), Londrina, PR, Brazil* ; [5] *IDR-Paraná/UTFPR (Undergrad Student), Londrina, PR, Brazil* ; [6] *IDR-Paraná, Londrina, PR, Brazil* ; [7] *Embrapa Coffee/Universidade Federal de Viçosa, Viçosa, MG, Brazil*

Rationale:
Leaf rust is one of the most harmful coffee diseases. *Coffea* spp. resistance factors S_H1-S_H9 are known. S_H3 resistance factor from *C. liberica* has been valued because it delivers durable resistance to the leaf rust. TseLeaf rust is caused by the fungus *Hemileia vastatrix*, and at least 15 physiological races were identified in Brazil. We recently proposed structural models for six *C. liberica SH3-Rx-CC-NBS-LRR* gene variants. Working *in silico* we recently demonstrated that S_H3 loci are complex and can display four up to eight *SH3-NBS-LRR*gene variants placed in chromosomes 3 from different *Coffea*, with additional variants identified in chromosomes 6 for some species. The variant placement resemble the complexity observed at the *C. arabica* cv. IAPAR59 S_H3 locus, accessed a decade ago. This work aims to contribute for *SH3-NBS-LRR* variant divergence analyses, which are highly interesting to investigate structure x species-specific pathogen effector recognition

Methods:
Via PACBio target-sequencing, S_H3 genes from a *C. arabica* plant with introgression from *C. liberica* (BA10 series), from differential genotypes CIFC H147/1, H151/1 and H153/2 used for *H. vastatrix* race typing, and a *C. arabica* var. Caturra selection were accessed. These five coffee genotypes express S_H2-3, S_H2-5, S_H-5, $S_H1,3,$-5, and S_H5, respectively. PACBio Hi-Fi reads were subjected to correction and assembly using the *canu* algorithm (v2), and to an additional round of *contig* assembling with a minimum of 97% identity throughout 3000 bases. Pairwise distance between aligned *contigs* were calculated (dnadist) and clustering was performed by the maximum likelihood method (without a molecular clock). Software were set to the default values (Phylip v3.698)

Results:
Contigs/variants produced had open reading frames for NBS-LRR resistance proteins, being seven from the BA10 coffee plant, three *contigs*/variants from each differential genotypes, and four from *C. arabica* var. Caturra. One additional *contig* for each differential genotype had no NBS-LRR-like open reading frame. Taking 2000 bases of carboxy-termini, directly involved in pathogen effector species-specific recognition, and relaying on the differential genotypes, clusters of S_H3, and $S_H3,5$ related variants were obtained.

Conclusions & Perspectives:
Coffee *SH3-NBS-LRR* variant seems to diverge according to their species-specificity, and could possibly interact with different fungus physiological races. *SH3-NBS-LRR* variant number/diversity could determine resistance to one or more fungus physiological race(s). This preliminary result shall be tested by variant expression analyses.

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Exploring the role of sugars in the Kawisari coffee resistance to *Hemileia vastatrix*

Azinheira Helena Gil[1,2] (hmga@edu.ulisboa.pt), Santos Marina do Rosário[1], Guerra-Guimaraes Leonor[1,2], Pinheiro Carla[3,4], Diniz Ines[1,2], Ferrari Valentina[1,5], Loureiro Andreia[2], Tavares Silvia[1,2,6], Silva Maria do Céu[1,2]

[1] *CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia, Universidade de Lisboa, Oeiras, Portugal* ; [2] *LEAF - Linking Landscape, Environment, Agriculture and Food Research Center, Instituto Superior de Agronomia, Universidade de Lisboa, Lisboa, Portugal* ; [3] *UCIBIO Applied Molecular Biosciences Unit, Department of Life Sciences, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [4] *Associate Laboratory i4HB Institute for Health and Bioeconomy, NOVA School of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal* ; [5] *Department of Biotechnology, University of Verona, Verona, Italy* ; [6] *Department of Plant and Environmental Sciences, Copenhagen Plant Science Center, University of Copenhagen, Copenhagen, Denmark*

Rationale:
Coffee leaf rust (CLR), a disease caused by the fungus *Hemileia vastatrix*, compromises the production of Arabica coffee (*Coffea arabica*), a species that accounts for almost 60% of the global coffee supply. Plants exert a tight coordination of carbon metabolism along growth and development either in normal or stressful situations. The control of this metabolism is of special interest in plant-fungus biotrophic interactions such as coffee rust once plants attempt to restrict pathogen access to resources such as sugars and sugar derivatives. RNAseq data from Kawisari leaves (resistance and susceptible samples) showed modulation of carbon metabolism as well as sugar transporters along the infection process. The sugar transporter activity might be correlated with sucrose degradation into glucose and fructose, which can be achieved by invertases enzymes. This work aims to unveil the role of sugar enzymes and sugar transporters in coffee rust resistance.
Methods:
Kawisari hybrid (*C. arabica* x *C. liberica*), a genotype used as a donor for resistance in Arabica breeding programs in India, was inoculated with urediniospores of *H. vastatrix* race II and race XIII to establish an incompatible (Resistance) and compatible (Susceptibility) interaction, respectively. The infection process was monitored by light microscopy, invertases enzymatic activities were evaluated by spectrophotometry and gene expression characterization by RT-qPCR.
Results:
The resistance was characterized by the restriction of fungal growth (more frequently in post-haustorial stages) associated with the hypersensitive response, accumulation of phenolic-like compounds in host cells and, haustoria encasement with callose. A significantly higher percentage of infection sites with host responses were observed in resistance than in susceptible. The highest enzymatic activities were observed for cell wall and vascular invertases at the latter stages of the infection process, particularly for resistance. Expression analysis of monosaccharide transporter genes by RT-qPCR is ongoing.
Conclusions & Perspectives:
Overall, this work will contribute to a better understanding of the role of sugars mobilization in *Coffea* sp. - *H. vastatrix*interactions, particularly in host resistance.

Risk factors associated with epidemics of coffee leaf rust (*Hemileia vastatrix* Berk. & Broome.) in Ethiopia

Bekele Kifle Belachew (kiflekef@gmail.com)

Plant Protection Department of Coffee Pathology Section, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia

Rationale:
Arabica coffee (*Coffea arabica* L.) is native from Africa, particularly from Ethiopia. Epidemics of coffee leaf rust (CLR), caused by the fungus *Hemileia vastatrix*, considered to be minor, but have become more frequent and severe in the country accompanying the expansion of commercial coffee plantations and changes in climate variables.

Methods:
Large-scale survey was conducted in the major coffee-growing regions of Ethiopia. Percent disease intensity (incidence and maximum severity) and crop management data were obtained from 405 farms distributed over 27 districts, 9 zones of Oromia and Southern Nations Nationalities and Peoples (SNNP) regions. The data were analyzed using a mixed model using R.

Results:
Based on the results, CLR was present in all farms with mean incidence ranging from 5 to 86.7% (mean = 35.3%) and severity ranged from 2.2 to 64.1% (= 22.5%). While CLR incidence did not differ among zones or districts based on a mixed model analysis, the effects of all agronomic factors and altitude, tested individually in the model, were significant. There was general trend of decreasing CLR intensity with the increase in altitude, but the agronomic factors overlapped and were confounded with the reduction/increase of CLR intensity at higher/lower altitudes. A multiple correspondence analysis showed the lowest incidence class (< 23%) associated with the use of intensively managed improved varieties grown at highest elevation class under shade. The highest incidence (>43%) was correlated with poorly managed local varieties grown under full sun at the lowest elevation class.

Conclusions & Perspectives:
Our data confirm CLR as a widespread problem serving as a warning for Ethiopian authorities and coffee growers to act towards a national plan to improve CLR management.

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Genetic diversity and population structure of *Hemileia vastatrix* (Berk. and Broome.) from Ethiopian coffee (*Coffea arabica*)

Bekele Kifle Belachew (kiflekef@gmail.com)

Plant Protection Department of Coffee Pathology Section, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Oromia, Ethiopia

Rationale:
In Ethiopia, coffee is the major cash crop accounting for 34% of the total export and 39% of agricultural export earnings of the nation. However, its production has been widely affected by economically important diseases. Coffee leaf rust (CLR), caused by *Hemileia vastatrix*, is becoming the most devastating diseass of Coffee in Ethiopia. Understanding the diversity and population structure of this pathogen is critically important for breeding programs targeting host resistance identification and for designing control strategies.

Methods:
This study was undertaken to characterize the genetic diversity and structure of 87 *H. vastatrix* populations collected from major coffee-growing areas of Ethiopia using Simple Sequence Repeat (SSR) markers. The characterization was done by applying 17 polymorphic SSR markers across the sample isolates. Principal coordinate analysis (PCoA) was computed for populations by GenAlEx v 6.52, using pairwise G'ST matrix. The unweighted pair group arithmetic mean average (UPGMA) trees were also constructed for populations and isolates using MEGA 7 to determine the relationship among populations as well as among isolates within a population.

Results:
Observed alleles per locus ranged from 2 to 13, with an average of 5.22. Diversity indices as, total Shannon diversity index (sH) and total Shannon pairwise diversity index was 0.89 and 0.92 respectively. The variation observed within population, was 92%. Most of the paired populations showed very low (< 0.07) genetic differentiation (FST) values, corresponding to high levels of gene flow between populations. The highest pairwise Nei and Fst values of genetic distance were observed between Agaro and Dilla (Nei=0.088 and Fst=0.043) populations, whereas the lowest were recorded between Awada and Bonga (Nei= 0.019 and Fst=0.01) populations.

Conclusions & Perspectives:
Populations of *H. vastatrix* in Ethiopia are highly variable and vast majority of genetic variation was distributed within all coffee growing districts of the country. The study provides baseline information for efficient screening of coffee genotypes for resistanct to CLR. Since the country is centre of origin for *Coffee arabica* and the pathogen (*H. vastatrix*), this work has critically important for future Global coffee leaf rust pathogen study.

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Transcriptomic e interactomic profiling of the *Coffea-Hemileia vastatrix* pathosystem

Alves Danúbia Rodrigues[1] (danubia.rodriguesalves@gmail.com), Almeida Dênia Pires de[1, 2], Silva Edson Mario de Andrade[1], Barreiros Pedro Ricardo Rossi Marques[1], Almeida Denise Pires de[1], Mendes Tiago Antônio de Oliveira[3], Caixeta Eveline Teixeira[1, 4]

[1] *Institute of Biotechnology Applied to Agriculture, Universidade Federal de Viçosa - UFV, Viçosa, MG, Brazil* ; [2] *denia_pires@hotmail.com, Viçosa, Brazil* ; [3] *Department Biochemistry and Molecular Biology, Universidade Federal de Viçosa - UFV, Viçosa, MG, Brazil* ; [4] *Embrapa Café, eveline.caixeta@embrapa.br, Embrapa, Brasíla, DF, Brazil*

Rationale:
The fungus *Hemileia vastatrix* is the pathogen that causes coffee leaf rust, a devastating disease in coffee production worldwide. Knowledge of pathogen attack strategies and how the plant defends itself during plant-pathogen interaction is crucial for the development of control alternatives. However, the *Coffea-H. vastatrix* interaction is still poorly studied. This study aimed to investigate the gene expression profile and analyzed interactome of putative candidate genes associated with coffee resistance to *H. vastatrix*.

Methods:
Global network of protein interactions was modeled, considering the interactions of coffee proteins with *H. vastatrix* proteins and in between proteins from the coffee itself. The global interactome was filtered using the transcriptome data of the incompatible interaction, considering up-regulated genes in CIFC832/1 when inoculated with *H. vastatrix*. In order to investigate the biological functions of the interactome clusters, a functional enrichment analysis was performed using a Gene Ontology functional annotation.

Results:
The integration of transcriptomic and interactomic data allowed to obtained two networks. One network corresponds to the interactions between the up-regulated genes 12 hours after infection (hai) in the incompatible interaction with secreted and/or transmembrane proteins of *H. vastatrix* and the other to the up-regulated genes 24 hai. The interactome with 12 hai data contains 648 nodes and 2807 connectors; the 24 hai data contains 646 nodes and 2606 connectors. We identified proteins associated with resistance and signaling cascade, such as, activation of the pathway brassinosteroid mediated signaling; response to wounding; gene silencing; signaling pathway; regulation of innate immune response; transmembrane receptor protein serine/threonine kinase; and regulation of intracellular protein kinase cascade. The results of gene expression, functional annotation of the proteins, study of the interaction between them and which biological functions in the pathosystem support the hypothesis that the proteins present in these clusters are strong candidates to act directly in the pre-haustorial resistance of coffee plants to *H. vastatrix*.

Conclusions & Perspectives:
The analysis of protein-protein interactions and biological processes involved in these interactions allowed the description of new candidate genes acting directly on the coffee resistance to *H. vastatrix*. The results are valuable for breeding programs aimed at developing coffee cultivars with durable resistance, in addition to enabling a better understanding of the *Coffea-H. vastatrix* pathosystem.

Funding: CNPq, FAPEMIG, CBP&D/Café and INCT-Café

A simple bioassay technique for screening the plant tolerance to Coffee White Stem Borer, *Xylotrechus quadripes* (Coleoptera: Cerambycidae)

Ganesharao Halemane Seetharama[1] (seetharamhg@gmail.com), Amsalingam Roobakkumar[1], Madhihalli Shanmukhappa Uma[1], Peketi Krishna Reddy[1], Kilannaparambil Tintumol[1], Nayani Surya Prakash Rao[2]

[1] *Division of Entomology, Central Coffee Research Institute, Coffee Board, Chikkamagaluru, Karnataka, India* ; [2] *Plant Breeding & Genetics, Central Coffee Research Institute, Coffee Board, Chikkamagaluru, Karnataka, India*

Rationale:
The bioassay techniques are very handy and important in understanding plant-insect interactions, especially for assessing the susceptibility/tolerance of plants to insect pests. So far, coffee researchers are relying only on the natural field infestation data to measure the tolerance level of different cultivars against Coffee White Stem Borer (CWSB). Nevertheless, as environmental conditions might influence the field infestation, development of a simple bioassay technique is an imperative need to understand the exact tolerance of cultivars against CWSB.

Methods:
A new and simple technique was developed by inoculation of CWSB adults through caged releases using plastic vials of 25 ml with a size of 7.5 × 2.5 cm (l×b). A small window of 4.5 x 1.0 cm was made at one side of the vial and fixed to the coffee plants with adhesive tape positioning the cut opened portion of vial facing the stem surface. A pair of mated adults was released inside the vial and periodically the caged stem portion was cut and observed for egg laying and larval mortality. Diffrent aArabica cultivarswere sscreeningusinrough bioassay method.

Results:
The new bioassay method was found very efficient in generating the data on the infestation process in a sequential manner starting from egg laying, egg mortality and survival of larval stages on the stem. This bioassay technique was deployed for field screening of different cultivars and revealed that S.4595 was highly tolerant and Cauvery was highly susceptible to CWSB comparatively. These findings are in line with the natural field infestation data. Further, this method provides an insight to the researchers on the reasons behind the tolerance mechanism of the cultivars.

Conclusions & Perspectives
The new bioassay method was validated across the coffee genotypes and proved to be an efficient tool in tracking the host pest interactions and assessing susceptibility, as well as relative tolerance. As this technique generates precise information on the response of the host to the pest which is more reliable than the general field infestation data. Hence, this technique can be effectively used in breeding programs for assessing CWSB tolerance. is and also useful in the evaluation of new pesticide molecules to develop a pragmatic IPM strategy for CWSB.

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Using a multipronged approach to combat coffee leaf rust in Hawaii

Keith Lisa (Lisa.Keith@usda.gov), Luiz Blaine, Sugiyama Lionel, Matsumoto Tracie

USDA Agricultural Research Service, Hilo, HI, United States

Rationale:
Coffee is one of the most economically valuable specialty crops for which Hawaii is famous and is produced commercially on six islands by over 1,470 growers. Hawaii's coffee industry, conservatively valued at $100M per year [1], is at risk due to the recent arrival of coffee leaf rust (CLR) caused by the obligate parasitic fungus, *Hemileia vastatrix* [2].
Methods:
To monitor and mitigate the impact of CLR in Hawaii, researchers developed tools for early detection and strategies for disease management to disseminate to coffee growers.
Results:
CLR was first reported on Maui in late October 2020, discovered in Kona on Hawaii Island in early November 2020, and rapidly spread throughout the state. High spore load, ease of dispersal and the environmental heterogeneity across Hawaii's coffee-growing landscape, combined with differences in management practices, high production costs, and labor shortages will make CLR control extremely difficult. Compounding these challenges is that all coffee genotypes grown on a large scale in the state are susceptible to CLR and few chemical and biological control products are approved for use.
Conclusions & Perspectives:
CLR threatens not only the yield and quality of Hawaii-grown coffee, but also the economic viability of the industry and preservation of cultural heritage. Various aspects of research to safeguard Hawaii's coffee industry against *H. vastatrix*, including fungicide testing, variety screening, and results from surveys of potential fungal antagonists, will be discussed.

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Biocontrol of coffee Shot hole borer, *Xylosandrus compactus* Eichhoff (Coleoptera: Curculionidae) using entomopathogens

Madhihalli Shanmukhappa Uma[1] (umaccri@gmail.com), Amsalingam Roobakkumar[1], Peketi Krishna Reddy[1], Kilannaparambil Tintumol[1], Halemane Ganesharao Seetharama[1], Krishna Lokesh Naik[2]

[1] *Division of Entomology, Central Coffee Research Institute, Coffee Board, Chikkamagaluru, Karnataka, India* ; [2] *Department of Applied Zoology, Sahyadri Science College, Kuvempu University, Shivamogga, Karnataka, India*

Rationale:

Shot Hole Borer (SHB) or Black twig borer is one of the important pests of coffee. The incidence of SHB has been on the rise in recent years, especially in Robusta (*Coffea canephora*) causing significant damage particularly in young plants. Adult females bore and tunnel inside the succulent twigs and lines the wall of the tunnel with symbiotic *Ambrosia* fungus. The unnelling disrupts the flow of nutrinturn ladings to wilting, drying and loss of bearing wood. The current study was carried out to test the efficacy of various bioagents against SHB, to strengthen the existing IPM. Biocontrol method is gaining importance in agricultural crops, as it is an alternative to pesticide, ecologically safe and supports agricultural sustainability.

Methods:

A total of six entomopathogens viz., *Beauveria bassiana, Metarhizium anisopliae, Lecanicillium lecanii, Trichoderma harzianum, Bacillus subtilis* and *B. cereus* were evaluated for their efficacy against SHB under *in-vitro* and *in-vivo* conditions. The bioagents were prepared at 1×10^6 to 1×10^8 conidia ml^{-1} for fungal cultures and 1×10^3 to 1×10^5 conidia ml^{-1} for bacterial cultures, respectively. The *in-vitro* and *in-vivo* studies were carried out by following the standard protocols and recdinged the mortality.

Results:

The *in-vitro* studies indicated that among the bioagents tested, *B. bassiana, T. harzianm* and& *M. anisopliae* produced statistically significant mortality (≥ 95%) of eggs, larvae, pupae, and adult stages at $1x10^7$ conidia ml^{-1}.The field efficacy studies revealed that *B. bassiana* caused statistically significant mortality of 82.5% of adults and 76.0% of developmental stages inside the twigs. The aerial mycelial growth and mortality were noticed by 3rd day after treatment in both *B. bassiana* and *T. harzianum*, and mycelia covered coely on life stages by 5th day. The results also indicated the potential ability of the *B. bassiana* mycelium, to grow on the adults at the entrance hole and subsequently spread to the developmental stages of SHB in the galleries, thus resulting in death of the progenies.

Conclusions & Perspectives:

The bioagents evaluated in the study revealed the potential of *B. bassiana* for the management of Shot hole borer. As *B. bassiana* is being recommended for the management of Coffee Berry Borer (Broca), the same can be integrated as a component in Integrated Pest Management of SHB. However, the efficacy of *B. bassiana* depends on environmental conditions for its establishment and persistence in field. In this regard, studies are in progress towards the development of a commercial formulation of *B. bassiana* to reduce the reliance on synthetic pesticides.

Evaluation of Crotale 46 EC insecticide for management of coffee thrips (*Diarthrothrips coffeae*) in Northern Tanzania

Magina Fredrick[1] (flkmagina@gmail.com), Mbwambo Suzana[1], Kilambo Deusdedit[2]

[1] *Good Agricultural Practices (GAPs) Research, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania* ; [2] *Administration, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania*

Rationale:
The coffee thrps, eis a potentially important insect pest for Arabica coffee in East Africa including Tanzania. The pest causes heavy defoliation of leaves during prolonged drought. In Tanzania it used to be a minor pest but since 2014 serious outbreaks have occurred in isolated areas. The Arysta Chemical Company has come up with a new product Crotale 46 EC, which TaCRI collaboratively evaluated against thrips in the field.

Methods:
The evaluation of the pest was done at Burka and Oldeani coffee estates (Arusha region) from April to May 2022, using a CRBD with four replications. Six treatments including; Crotale 46 EC at a rate of 25 mls, 20 mls, 15 mls and 10 mls/20 lts of water, and Chlorpyrifos 480 g/l (standard) at a rate of 20 mls/20 lts of water and control were applied. The coffee leaves with thrips were randomly selected one leaf/ tree and ten adult thrips per leaf. The mortality rate of thrips was counted after every 24, 48 and 72hrs, summarized to excel sheet and subjected to ANOVA using GenStart statistical package software.

Results:
Results indicate that the treatments had a significant effect ($P \leq 0.05$) on the mortality rate of thrips observed on the leaves of coffee on different concentrations applied across locations of coffee estates. Crotale 46EC at a rate of 25 mls in 20 L of water performed the best followed by 20 mls, 15 mls and 10 mls/20 L. The mortality rate ranged between 8.3 to 100% from day one (24hrs) to day three (72hrs).

Conclusions & Perspectives:
Crotale 46EC at a rate of 10 mls/ 20 L is recommended for economic reasons to be used by farmers because it resulted in a 100% mortality rate in the same way as the check (Chlorpyrifos 480 g/l) in all locations for the 3rd day of application. The chemical could be registered and incorporated into the IPM programme against coffee thrips in Tanzania.

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Occurrence and evaluation of insecticides and biopesticides for the management of coffee snails and slugs in Southern Tanzania

Magina Fredrick[1] (flkmagina@gmail.com), Mbuba Aden[1], Pangalas Dismas[2], Mbwambo Suzana[1], Kilambo Deusdedit[3]

[1] *Good Agricultural Practices (GAPs) Research, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania* ; [2] *Technology Transfer and Training, Tanzania Coffee Research Institute (TaCRI), Mbeya, Kilimanjaro, Tanzania* ; [3] *Administration, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania*

Rationale:
In recent years the Tanzania coffee industry has witnessed an outbreak of snails and slugs attacking coffee in the Southern Highlands of Tanzania, a problem first reported in the 2019/20 season. The pest attacks coffee stems, branches and leaves during the rainy season and causes substantial damage. Farmers had taken control initiative by collecting and destroying the adults and eggs.

Methods:
TaCRI was surveyed to establish the extent and distribution of the pest by interviewing farmers about the original and its causative agent. We performed a pilot screening of various chemicals, botanicals and& baits for the pest as an alternative management practices. As a short-term plan, TaCRI has created awareness to farmers on the recommended control measures.

Results:
Results from interviewed farmers indicate that the distribution of the pest covers the whole coffee growing area, and the causative agent of the pest was speculated to originate from the natural forestry and forced to follow new niches due to climate change. Results from screening Konokono Bait Pellets 4%, Polytrin 40 EC, garlic and mixture of honey + yeast to affect the pest. In addition, we trained 67 farmers as a short-term plan for the recommended control practices such as farm sanitation, proper pruning, scouting and killing of adults, regular turning of mulch, trapping, use of barriers, biological control agents and avoidance of evening irrigation.

Conclusions & Perspectives:
Perfecting the appropriate dosages of chemicals, botanicals and baits for the traps are recommended for further evaluation and be incorporated in the IPM package. Identification of the pest to species level, biology and ecology are required for its proper management in the future. Also, sensitization on the occurrence and how to manage the pest in the fieldea of priority for farmers.

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The biodiversity and farmer practices in different climate and their effect on the infestation rate of coffee berry borer

Maqsalina Marich Nur[1, 2] (marichmaqsalina@apps.ipb.ac.id), Beilhe Leïla Bagny[3], Wagianto Wagianto[4], Hidayat Purnama[1]

[1] *Departement of Plant Protection, IPB University, Bogor, Indonesia* ; [2] *Department of Agricultural and Ecological Sciences, University of Montpellier, Montpellier, France* ; [3] *UMR PHIM, CIRAD, Montpellier, France* ; [4] *PT Indo Cafco, Medan, Indonesia*

Rationale:

The coffee berry borer (CBB), *Hypothenemus hampei* (Coleoptera: Scolytinae) is a major coffee pest in all coffee producing countries, including Indonesia [1] causing important yield and economic losses [2]. CBB incidence can be modulated by farmers' practices, biotic and abiotic factors. In this study, we propose to investigate the effects of all these factors on CBB infestation rate in two regions of Indonesia, Simalungun Regency in North Sumatra) and Bandung Regency in West Java). Both regions are mainly composed of Arabica coffee plantations [3]. The North Sumatra region is submitted to an equatorial climate which has a bimodial type of rainfall whereas the West Java region is a typical tropical humid climate with only one peak of rain.

Methods:

In this study, twenty study plots/region were selected at an altitude around 1200m, with two levels of practices regarding CBB control (10 farms with control strategy and 10 farms without control) and based on the number of associated trees species. In each farm, all coffee berries (attaked or not by CBB) were counted on 120 branches on 30 randomly selected trees during five months (from January to May 2023). Infestation rate of CBB was calculated monthly. Farmers used to associate more trees species to coffee plantation in North Sumatra (14 max) than in West Java (5 max).

Results:

Global incidence of CBB is higher in North Sumatra than West Java whatever the level of associated treel. The climate effect on this dynamics is under investigation. The effect of the number of associated trees species on CBB incidence is still unclear. We assumed that the effect of associated biodiversity on CBB is linked to microclimate modification and additional data are needed to confirm that. Our result demonstrated that control strategies implemented by farmers are efficient to reduce CBB infestation

Conclusions & Perspectives:

Results obtained in this study have never been published for these regions. Based on these results we will adapt an existing agent-based model developed in Costa Rica on CBB infestation rate dynamics. This model will then be presented o Iindonesian farmers to support implementation of efficient control strategies that are adapted to local context.

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The Physiological Race of the first *Hemileia vastatrix* (Coffee Leaf Rust) discovered in Hawaii

Matsumoto Tracie[1] (tracie.matsumoto@usda.gov), Keith Lisa[1], Sugiyama Lionel[1], Fukada Mach[2], Nagai Chifumi[3], Pereira Ana Paula[4, 5], Céu Silva Maria[4, 6], Várzea Vitor[4, 5]

[1] *Daniel K. Inouye Pacific Basin Agriculture Research Center, USDA ARS, Hilo, HI, USA* ; [2] *University of Hawaii Maui College, Kahului, HI, USA* ; [3] *Hawaii Agriculture Research Center, Waipahu, HI, USA* ; [4] *Centro de Investigação das Ferrugens do Cafeeiro, Universidade de Lisboa, Oeiras, Portugal* ; [5] *LEAF, Linking Landscape, Environment, Agriculture and Food, Universidade de Lisboa, Lisbon, Portugal* ; [6] *Universidade de Lisboa, Lisbon, Portugal*

Hawaii's coffee industry, produced commercially on six islands by over 1,470 growers on ~10,000 acres, is conservatively valued at $100M per year. Until late October 2020, Hawaii was the only major coffee producing region of the world that was free of Coffee Leaf Rust (CLR). Since its introduction (Keith et al. 2022), CLR has rapidly spread throughout the state and can be found on coffee farms and feral coffee. More than 55 different rust races from coffee growing countries worldwide have been identified (Silva et al. 2022). In June 2021, nine spore samples from symptomatic cultivated and feral plants 'Typica' growing on three islands (Hawaii Island: 3, Maui: 5, Molokai: 1) were collected in gelatin capsules using a G-R Electric Manufacturing portable vacuum pump with a mini cyclone spore adapter. The samples were sent to the Coffee Rust Research Center (CIFC) in Portugal. At CIFC, the urediniospores were bulked on susceptible genotype 849/1 Matari and inoculated on a set of coffee differentials following a standard race-typing procedure (Várzea and Marques 2005). The genotype of virulence of rust samples was inferred according to Flor's gene-for-gene theory (Silva et al. 2022). The genes of virulence v2, v4, and v5 (Race XXIV) were identified in all rust samples from all islands in Hawaii, supporting the theory of a single introduction to the state, which subsequently spread. Race XXIV was previously characterized at CIFC and is commonly found in the majority of coffee-growing countries in South and Central America, Africa and Asia (CIFC's data base). According to Figueiredo & Arruda (1974), race XXIV is considered highly aggressive with a high spore germination rate, medium germ tube length, and short incubation period required for infection. Race XXIV is pathogenic to all coffee Arabica genotypes with the resistance genes SH5 or SH2,5 like varieties Blue Mountain, Bourbon, Catuaí, Caturra, Kent's, Kona, K7, Mundo Novo, SL 28, SL 39, as well as Accession «Agaro» with resistance genes SH4,5 (CIFC's records). On the other hand, this race is not virulent to some other Arabica genotypes, such as Geisha (SH1,5), S.288 (SH3,5), and Dilla & Alghe (SH1). Race XXIV is unable to infect derivatives of interspecific tetraploid hybrids like the groups Catimor and Sarchimor (Bettencourt and Rodrigues 1988). This is the first report of race XXIV on *Coffea arabica* in Hawaii. This finding is essential to evaluate the potential resistance of coffee germplasm existing in Hawaii or to be introduced in this region to develop new varieties.

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Replant Treatments for Coffee in Root-knot Nematode Infested Fields

Myers Roxana[1] (roxana.myers@usda.gov), Kawabata Andrea[2], Mello Cathy[1], Miyahira Matthew[2], Yamauchi Nicholas[3], Nakamoto Stuart T.[4]

[1] *Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, United States Department of Agriculture, Agricultural Research Service, Hilo, Hawaii, United States* ; [2] *Department of Tropical Plant and Soil Sciences, University of Hawaii at Manoa, College of Tropical Agriculture & Human Resources, Kealakekua, Hawaii, United States* ; [3] *Kona Research Station, University of Hawaii at Manoa, College of Tropical Agriculture & Human Resources, Kealakekua, Hawaii, United States* ; [4] *Department of Human Nutrition, Food, and Animal Sciences, University of Hawaii at Manoa, College of Tropical Agriculture & Human Resources, Honolulu, Hawaii, United States*

Rationale:
In Hawaii coffee plantations, *Meloidogyne konaensis*, Kona coffee root-knot nematode, is highly pathogenic on *Coffea arabica* cv. Typica. The nematodes feed on the taproot causing galling, cracking, and loss of feeder roots. The destruction of the root system leads to defoliation, toppling, yield reductions, and eventually mortality of susceptible trees. In this study, chemical and biological nematicides were evaluated for their efficacy at reducing *M. konaensis* populations when replanting in infested fields.
Methods:
Fluopyram, spirotetramat, *Burkholderia* spp. Strain A396, *Bacillus subtilus* + arbuscular mycorrhizal fungi (AMF), 1% papaya seed, and compost were compared to an untreated control in a greenhouse bioass.*offea arabica* cv. Typica and *C. liberica* cv. Arnoldiana were planted in pots inoculated with *M. konaensis* and treated quarterly. Nematode reproduction, plant growth, root weight, and root health were evaluated. A field trial was also conducted to evaluate spirotetramat, *Burkholderia*, and compost in replanted Arabica trees grafted on Liberica rootstocks and nongrafted Arabica trees.
Results:
In the potted plant bioassay, the lowest nematode populations in Arabica roots were observed in fluopyram treatments, while in Liberica roots, *Bacillus*+AMF and compost treatments had the lowest nematode numbers. Plant growth was highest in Arabica and Liberica seedlings treated with fluopyram. Liberica root weights were highest in fluopyram and compost treatments. However, no differences were observed in root health ratings among treatments in both coffee species. In the field, *M. konaensis* populations were lowest in grafted and nongrafted trees treated with spirotetramat. Crop yields were highest in grafted trees planted in soil mixed with compost with no yield differences observed in nongrafted trees.
Conclusions & Perspectives:
Chemical nematicides were most effective at reducing nematode populations when replanting coffee in *M. konaensis* infested soil. Fluopyram applications also improved shoot and root growth. Incorporating compost into the planting hole had varying results but showed promise as a potential management tool.

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Applicability and effectiveness of the rapid detection method for leaf rust disease resistance in Arabica coffee

Saengsai Weerakorn[1] (weerakorn.saengsai@gmail.com), Ruttawat Benjawan[2], Jarintorn Siriporn[3], Khomarwut Chatnapa[4]

[1] *Department of Agriculture, Field Crop and Renewable Energy Crop Research, Muang, Khon Kaen, Thailand* ; [2] *Department of Agriculture, 1Khon Kaen Field Crops Research Center, Khon Kaen, Thailand* ; [3] *Department of Agriculture, Chiang Mai Royal Agricultural Research Center, Chiang Mai, Thailand* ; [4] *Department of Agriculture, Phare Agricultural Research and Development Center, Phrae, Thailand*

Rationale:
In Thailand, coffee leaf rust (CLR), caused by the fungus *Hemileia vastatrix,* is the main disease that affects the Arabica coffee crop especially those that are grown in northern Thailand. The disease starts spreading at the end of the rainy season. Symptoms first appear as small chlorotic spots preceding the differentiation of supra stomatal, orange-colored uredinia. The severity of the symptoms depends on the sensitivity of the coffee varieties to disease and environmental factors. The screening for CLR resistance generally involves a long process of pathogenicity tests in coffee seedlings that are vulnerable to environmental factors during the testing. This study aimed to evaluate the applicability and effectiveness of the rapid screening method using leaf disks to test CLR resistance in Arabica coffee..
Methods:
Hemileia vastatrix Race 37 was used on 144 coffee genotypes, including 8 Arabica coffee varieties and 1 hybrid. The inoculation was done in the 1.5 cm in diameter of coffee leaf disks that placed in 9 cm glass plate and incubated at 20° C with lighting for 16 hours, relative humidity at 90%.
Results:
The population of No. 1/1 B2T5 and 1/4 B3T3 showed small lesion sizes indicating highly resistant traits while Chiang Mai 80 showed moderately resistance. This result was consistent with the finding that *PR1b* and *PR10* gene nes associated with coffee leaf rust disease n Aarabica coffee. *PR1b* and PR10 genes were found to be upregulated in coffee leaf rust resistance population including Chiang Mai 80 population and No. 1/1 B2T5 and 1/4 B3T3.[2].
Conclusions & Perspectives:
This result support the applicability and effectiveness of this detection method for leaf rust disease resistance n Aarabica coffee and thus can be used as a rapid and reliable method for the screening of resistance to coffee leaf rust disease in the control testing environment.

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Resistance of Arabica coffee cultivars to Phoma leaf spot

Sera Tumoru[1, 2] (tsera01@gmail.com), Bortolato Kawana Silva[1, 3], Patrício Flávia Rodrigues Alves[4], Carducci Fernando Cesar[1, 2], Mariucci Junior Valdir[1, 3], Pereira Carlos Theodoro Motta[1, 3], Shigueoka Luciana Harumi[1, 2], Sera Gustavo Hiroshi[1]

[1] *Plant Breeding, IDR-Paraná, Londrina, Paraná, Brazil* ; [2] *Consórcio Pesquisa Café, Brasília, DF, Brazil* ; [3] *Agronomy, UEL, Londrina, Paraná, Brazil* ; [4] *Plant Pathology, Instituto Biológico, Campinas, São Paulo, Brazil*

Rationale:
Phoma leaf spot (PLS) is a fungal disease of great importance in coffee crop. The main causal agent is *Boeremia exigua* pv. *coffeae*, formerly classified as *Phoma tarda*. Despite being a relevant disease for coffee growing, little is known about the genetic resistance of cultivars to PLS. Therefore, the aim of this study was to evaluate the resistance of cultivars to two isolates of *B. exigua* pv. *coffeae*.

Methods:
Resistance to PLS was evaluated in the cultivars IAPAR 59, IPR 99, IPR 100, IPR 102, IPR 103, IPR 104, IPR 106, IPR 107, IPR 108, Catuaí Vermelho IAC 99, Mundo Novo IAC 376-4, Icatu Vermelho IAC 4045 and Catucaí Amarelo 2SL. The susceptible and resistant controls were, respectively, the cultivars Catuaí Vermelho IAC 99 and Catucaí Amarelo 2SL. Two isolates of *B. exiga* pv. *cCoffeae* (IBLF 1199 and IBLF 1208) from Instituto Biológico were inoculated, which came from two municipalities in Minas Gerais. Eight seedlings of each genotype were used, four for each isolate. Inoculation was performed on the last pair of leaves, completely expanded from each seedling. The experiment was carried out in a factorial scheme (13 cultivars x 2 isolates), in a completely randomized design. Data from the variable % injured leaf area (%ILA) were submitted to statistical analysis.

Results:
There was a significant interaction between cultivars x isolates, indicating the presence of different biotypes or physiological races. The cultivars most resistant to IBLF 1199 were IPR 99, IPR 102, IPR 103, IAPAR 59 and Catucaí Amarelo 2SL, as they presented the lowest means of %ILA and differed from the susceptible control. The most susceptible cultivars were Mundo Novo, IPR 107, IPR 100, IPR 104, IPR 108, Icatu Vermelho IAC 4045 and IPR 106, as all did not differ from Catuaí. IPR 99 and IPR 102 were more resistant to IBLF 1208, and both differed from the susceptible control. IPR 103 and Catucaí Amarelo 2SL showed intermediate resistance to IBLF 1208, they did not differ from IPR 99 and IPR 102, but differed from IPR 107, which was the most susceptible. The other cultivars did not differ from Catuaí. IBLF 1208 showed the highest overall mean of %ILA, indicating that it is a more aggressive isolate.

Conclusions & Perspectives:
IPR 99, IPR 102, IPR 103, Catucaí Amarelo 2SL and IAPAR 59 were resistant to IBLF 1199, while the first two were also resistant to IBLF 1208. IPR 103 and Catucaí Amarelo 2SL showed intermediate resistance to IBLF 1208. These results indicate the probable existence of biotypes or physiological races of *B. exigua* var. *coffeae* and that, in the evaluated genotypes, the type of resistance is qualitative and quantitative.

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Evaluation of virus-induced gene silencing (VIGS) in coffee plants

Ribeiro de Barros Danielle[1], Diniz Inês[2, 3], Guerra-Guimarães Leonor[2, 3], Gil Azinheira Helena[2, 3], Silva Maria do Céu[2,3] (mariaceusilva@isa.ulisboa.pt), Batista Dora[2, 3]

[1] *Departamento de Fitossanidade, Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul, Brazil.* [2]*CIFC - Centro de Investigação das Ferrugens do Cafeeiro, Instituto Superior de Agronomia (ISA), Universidade de Lisboa, Oeiras, Portugal*; [3]*LEAF-Linking Landscape, Environment, Agriculture and Food Research Center, Associate Laboratory. TERRA, ISA, Universidade de Lisboa, Lisbon, Portugal*

Rationale:
Virus-induced gene silencing (VIGS) is an effective method for gene silencing that uses a plant's antiviral defensive mechanism to suppress the expression of specific invasive viral transcripts. It downregulates endogenous genes by utilizing the posttranscriptional gene silencing machinery of plants and prevent systemic viral infections. VIGS is an RNA-mediated reverse genetics technology that has evolved into an indispensable approach for analysing the function of genes. VIGS has been adapted to many angiosperm species, allowing the analysis of gene functions in species whose genetic transformation is far from routine. With a vast amount of sequence information available for coffee, VIGS might provide a means to analyse the functions of candidate genes previously identified in large genomic or transcriptomic studies. To further elucidate the functional role of coffee resistance related-candidate genes, this study aims to test the tobacco rattle virus (TRV) vector system for coffee and tune the inoculation conditions and the efficiency of the transient expression process.

Methods:
In this study, the tobacco rattle virus (TRV1 and TRV2) vector carrying a *Coffea arabica* phytoene desaturase gene (*CaPDS*) was used. After sequencing, the TRV2:*CaPDS* construction was transformed into Agrobacterium *tumefaciens* (strain C58C1). Coffee plants at two developmental stages (hypocotyls and seedlings) were agroinfiltrated and root dipped with TRV1+TRV2:*CaPDS* using different bacterial culture concentrations. As a positive control, TRV1+TRV2:*CaPDS* construction was also agroinfiltrated in tobacco (*Nicotiana benthamiana, Nb*) as well as the TRV1+TRV2:*NbPDS* construction. Inoculated plants were regularly monitored for the detection of the albino phenotype resulting from the effectively silencing of *PDS* gene expression.

Results:
Coffee seedlings agroinfiltrated with TRV1+TRV2:*CaPDS* construction showed some chlorosis in the infiltrated leaves, but no albino phenotype was observed in the newly grown leaves (for all bacterial culture concentrations tested). No symptoms were observed when using agroinfiltration of hypocotyls or inoculation by dipping. In contrast, agroinfiltration of tobacco with both PDS constructions resulted in an albino phenotype, confirming that the TRV2:*CaPDS* construction is working.

Conclusions & Perspectives:
This was the first tentative approach to establish a functional gene study using VIGS in coffee plants. Since no systemic silencing of the *PDS* gene in coffee was observed and several conditions can interfere with the success of VIGS assays, other viral vector systems, bacterium strains, culture concentrations, and inoculation methods are under study.

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Inducing water stress in new Robusta coffee varieties to enhance drought Tolerance

Amoa Amoa Jésus (jesus.amoa@cnra.ci), Kadjo Aya Marie-Louise

Centre National de Recherche Agronomique, Man, Tonkpi, Côte d'Ivoire

Rationale:
This study aimed to evaluate the water stress tolerance of new Robusta coffee varieties through a greenhouse experiment conducted in western Côte d'Ivoire. The objective was to identify Robusta genotypes that are tolerant to induced water deficit.
Methods:
Twelve genotypes derived from Guinean and Congolese Robusta clones, aged six months, were selected from the Divo research station. These genotypes were subjected to water stress for four weeks, followed by a recovery period of twenty-one days, with three levels of water supply (100%, 50%, and 0% of field capacity). Leaf chlorophyll content, dry matter distribution, relative growth rate, and recovery rate were measured and compared among all water regimes.
Results:
The results indicated a significant variation in the response of different genotypes to the water regimes. Notably, there were substantial differences observed among genotypes that were deprived of water for one month. Genotypes 7031 and 7054 exhibited a high shoot mass ratio, while genotype 7085 showed a high root mass ratio. Genotypes 7092, 7073, and 7042 demonstrated reduced growth but displayed a higher relative rate of increase in height and crown diameter. Genotype 7082 exhibited a higher total chlorophyll content (58.05 mg/l), whereas genotype 7070 had a lower content (17.04 mg/l). Genotype 7093 showed the highest survival rate after the recovery period (100%), followed by genotypes 7082, 7092, and lower survival was observed for genotype 7043 (32%).
Conclusions & Perspectives:
Based on the findings, it can be concluded that there is potential for breeding these new coffee varieties for drought tolerance. The most tolerant genotypes identified were 7082, 7092, 7093, 7075, and 7085. Future studies should focus on additional parameters such as somatic conductance, proline content, and reducing sugars, both in the field and in drought-prone areas, to further investigate the performance of these genotypes.

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Paths towards sustainability in Brazilian mountain coffee

Bliska Flavia[1] (flavia.bliska@sp.gov.br), Vegro Celso[2], Bliska Júnior Antonio[3]

[1] *Coffee Center, Agronomic Institute, Campinas, São Paulo, Brazil* ; [2] *Institute of Agricultural Economics, São Paulo, São Paulo, Brazil* ; [3] *State University of Campinas, Campinas, São Paulo, Brazil*

Rationale:
Coffee plantations in Brazilian mountain regions in general require renovation, as they have been cultivated for decades, with wider spacing and tall plants. In addition, the increased demand for labor and the shortage of local workers have been partially associated with the high unit cost of production. At the same time, the climate in these regions is favorable for plant development, high yield and, above all, good coffee quality. Therefore, a reasoned assessment of the sustainability of mountain coffees is important for the future of this activity and for local and regional development.

Methods:
This study first classified coffee farms into two major production systems – "mountain coffees" and "other coffees" – to assess its competitiveness and sustainability. Then, 1,182 structured questionnaires were applied, in the main Brazilian coffee regions, to quantify the effectiveness of the management of those farms.The questionnaires surveyed 64 elements related to making productive decisions, each one with a specific score [1]. The collected and systematized information established a management efficiency ranking in the coffee regions (scale from 1 to 9 for the degree of management), whose indicators were analyzed using principal component analysis (PCA).

Results:
In «other coffees», management evolution was strongly linked to the maximization of labor and process productivity, resulting in better product quality, greater competitiveness and greater resilience to price cycles typical of commodity coffee, especially in the regions of Alta Mogiana (state of São Paulo) and Cerrado (state of Minas Gerais). While in the «mountain coffees» the management indicators point to investments mainly in strategies that favor product differentiation and satisfaction of customers' expectations.

Conclusions & Perspectives:
The management gap between «mountain coffees» and «other coffees» can be compensated through innovations that can result in returns of scale with similar intensities for small and large coffee growers, such as digital agriculture 4.0. Additionally, the study identified a great opportunity for mutualistic or public policy actions aimed at strengthening mountain coffee growing.

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Strengthening smallholder coffee growers to access improved hybrid coffee seedlings in Tanzania

Jeremiah Magesa Marco[1] (jeremagesa@gmail.com), Malinga Sophia[2], Shao Godbless[3], Ng'homa Nyabisi[4], Pangalas Dismas[5], Hamad Almasi[6], Kilambo Deusdedit[7]

[1] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania* ; [2] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Kigoma, Kigoma, Tanzania* ; [3] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Mbinga, Ruvuma, Tanzania* ; [4] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Bukoba, Kagera, Tanzania* ; [5] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Mbozi, Songwe, Tanzania* ; [6] *Technology Transfer, Training & Advocacy, Tanzania Coffee Research Institute (TaCRI), Tarime, Mara, Tanzania* ; [7] *Appropriate Crop Improvement Research Programmes Continue to be Implemented, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania*

Rationale:
The coffee breeding program at Tanzania Coffee Research Institute (TaCRI) has led to the release of top hybrid coffee varieties that combine high yields and good beverage quality with resistance to the devastating diseases – coffee leaf rust (CLR) and coffee berry disease (CBD) for Arabica and coffee wilt disease (CWD) for Robusta. The improved coffee varieties are environmentally friendly as they do not require fungicide sprays to control CBD, CLR, and CWD. TaCRI's focus has been promoting the use of improved coffee seedlings for replanting programs. However, the challenge has been to meet the increasing demand for improved coffee seedlings with the current availability being far behind the demand. This paper describes the innovative approaches that TaCRI is using to help smallholder coffee growers access improved coffee seedlings for replanting programs to replace traditional coffee varieties susceptible to fungal and wilt diseases.

Methods:
In addressing the problem of increasing demand for high-yielding and disease-resistant improved Robusta and Arabica coffee seedlings, the Institute has placed much emphasis on supporting smallholder coffee growers to access the seedlings of improved coffee varieties. This has been successfully achieved through forming farmer groups of 20 to 30 members, establishing primary, secondary, and tertiary coffee nurseries, conducting backstopping visits, and providing technical skills to smallholders on seedlings multiplication by clonal, seeds, and grafting propagation techniques.

Results:
Notable achievements have been realized. TaCRI has established a decentralized and participatory system of seedlings multiplication and distribution in each coffee growing zone through its substations. The institute has formed a network of 284 farmers-managed nurseries (tertiary), 19 secondaries, and 6 primary nurseries with the capacity to multiply and distribute 20,000,000 seedlings annually thus increasing access to hybrid seedlings by smallholder coffee farmers for replanting programs. It is estimated that about 72 million hybrid seedlings have been multiplied distributed and planted and 42,000 ha equivalent to 17.5% of the coffee area in Tanzania has been replanted with improved hybrid coffee varieties since the new varieties were officially released.

Conclusions & Perspectives:
This paper describes our innovative approaches that have enabled coffee growers to access seedlings of improved coffee varieties for replanting programs, thus contributing to increased productivity and production. Therefore more efforts are needed to scale up the above approaches to meet the increasing demand for improved coffee seedlings.

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Shade and altitude effects on the ecophysiological performance of *Coffea arabica* L. under agroforestry system on Gorongosa Mountain, Mozambique

Leitão António[1] (antonioleitao@isa.ulisboa.pt), Cassamo Crimildo[2], Chiulele Rogério[3], Haarhoff Quentin[4], Moiane Sional[4], Rodrigues Ana[5], Marques Isabel[5], Partelli Fábio[6], Ribeiro-Barros Ana[7], Ramalho José[7]

[1] *Centro de Estudos Florestais, GeoBioTec, Universidade de Lisboa, Instituto Superior de Agronomia, Oeiras, Lisboa, Portugal* ; [2] *Faculdade Engenharia e Tecnologias, Universidade Pedagógica de Maputo, Maputo, Mozambique* ; [3] *Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane, Maputo, Mozambique* ; [4] *Gorongosa National Park, Goinha, Mozambique* ; [5] *Centro de Estudos Florestais, Universidade de Lisboa, Instituto Superior de Agronomia, Lisboa, Portugal* ; [6] *Departamento Ciências Agrárias e Biológicas, Univ. Federal Espírito Santo, Centro Universitário do Norte do Espírito Santo, São Mateus, Brazil* ; [7] *Centro de Estudos Florestais, GeoBioTec, Universidade de Lisboa, Instituto Superior de Agronomia, Lisboa, Portugal*

Rationale:
The *Coffea arabica* L. productivity is strongly affected by climate conditions and this crop has been pointed as vulnerable to climate changes. Crop ecophysiological performance is greatly determined by temperature and irradiation levels. The use of agroforestry systems (AFS) might have a positive role in this crop, while support the recovery of natural forest in the Gorongosa Mountain by using native trees for shading. In fact, shade conditions in these systems can reduce air temperature and increase air humidity, mitigating the expected global warming conditions. In this context, this researchaimed to assess the ecophysiological performance of coffee plants under three contrasting irradiances (deep shade, DS; moderate shade, MS; full Sun, FS) and three altitudes (650, 825 and 935 m) in the Gorongosa Mountain.
Methods:
To assess the impact of shade and/or altitude on leaf ecophysiological performance, nine plots of five years old *Coffea arabica* cv. Costa Rica plants were established with a split-plot design, with three altitudes representing the main plot (650, 825, 935 m) and the three assigned levels of light as sub-plot (DS, MS, FS). The net photosynthetic rate (Pn), stomatal conductance (gs), and chlorophyll *a* fluorescenceparameters were taken in four periods of the day (9 -10h; 11-12h; 13-14h; 15-16h) once a month, from April to September 2020.
Results:
Photosynthetic rates were generally higher in MS and FS during the dry and rainy periods. Regarding altitude, it was observed that the daily photosynthesis trends were similar among the different altitudes. However, coffee beans yield and quality among them varied significantly. Coffee plants from 825 and 935 m of altitude showed the highest yield. The greater daily net photosynthesis (Pn) was observed under FS and MS treatments and lower Pn was observed under DS treatment in all altitudes. Despite lower quantum efficiency of electron transport (Y(II)) in FS and MS, the high availability of light energy favored greater Pn in plants under these conditions. Higher altitude did not strongly alter the Pn pattern, but usually allowed the maintenance of greater stomatal conductance (gs) values under FS likely associated to greater water availability (to higher rainfall, as well as to fog persistence in some periods).
Conclusions & Perspectives:
Overall, this study showed that strong light restriction and excessive irradiation to some extend are both not optimal for the crop development and ecophysiology performance. The AFS management at MS associated to greater elevation suggested positive changes on some of the gas exchanges parameters, without decreasing coffee productivity as compared with FS.

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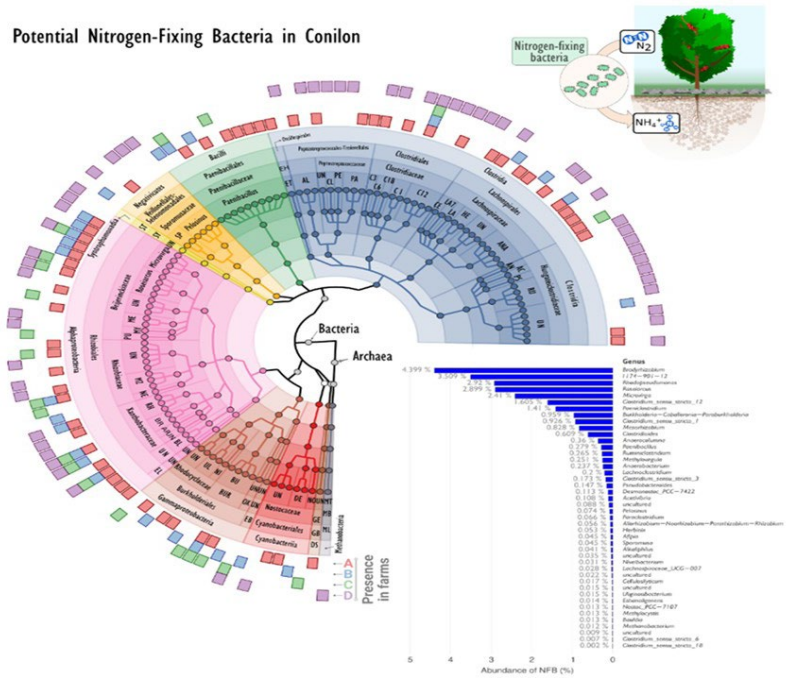
Bioclimatic factors and their relationship with bacterial and fungal diversity in Coffea canephora plantations Pierre ex A. Froehner

Rizzo Moreira Tais[1] (taisr.moreira@hotmail.com), Louza Lucas[2], Gomes Reis Veloso Tomás[3], Soares da Silva Marliane de Cássia[4], Quero José Luiz[5], Polonini Moreli Aldemar[6], Dos Santos Gomes Willian[7], Megumi Kasuya Maria Catarina[3], Borchardt Bullergahn Vilian[8], Rosa dos Santos Alexandre[9]

[1] *Coffee Design, Universidade Federal do Espírito Santo, Jerônimo Monteiro, ES, Braz* ; [2] *Coffee Design, Instituto Federal do Espírito Santo, Venda Nova do Imigrante, ES, Brazil* ; [3] *BioAgro, Universidade Federal de Viçosa, Viçosa, MG, Brazil* ; [4] *Bio, Uni, Viçosa, MG, Brazil* ; [5] *Forestry Engineering Department, University of Cordoba, Córdoba, Spain* ; [6] *Co, Ins, Ven, ES, BR* ; [7] *Coff, Universidade Federal do Espírito Santo, Alegre, ES, Bra* ; [8] *Universidade Federal de Viçosa, Viçosa, MG, Brazil* ; [9] *Centro de ciências agrárias e engenharias, Universidade Federal do Espírito Santo, Jerônimo Monteiro, ES, Brazil*

Rationale:
Soils encompass a varied range of physical, chemical, and biological variables that interact and impact critical ecosystem processes. We aim here to correlate these factors with soil microbiological markers in Coffea canephora plantation in the state of Espírito Santo with different edaphoclimatic features.
Methods:
We collected 180 samples of soil and fruits from these two species of Coffea on a national scale and sequenced the microbial DNA using the Illumina NovaSeq 600 platform. The sequences were processed using Qiime2 for denoising, chimera removal and annotation of sequences using the SILVA and UNITE databases.
Results:
Topographic, environmental and climatic conditions were carried out for a better understanding of each cultivation area and correlation with microbiological diversity.
Conclusions & Perspectives:
The bacterial community showed greater alpha diversity and homogeneity within each property than the fungal. In addition, there was a higher correlation between bioclimatic variables and bacterial diversity than fungal one. However, fungal diversity is more correlated with distance to forest fragments and potassium availability in Coffea canephora farms.



The Cladogram displays potential nitrogen-fixing bacteria (NFB) in soil of Coffea canephora.

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Digital mapping from scratches: Use of GIS to describe land use and selected soil properties of TaCRI Lyamungu Estate, Tanzania

Maro Godsteven (godsteven.maro@tacri.org), Mbwambo Suzana, Monyo Harrison, Mosi Epafra

Good Agricultural Practices Research, Tanzania Coffee Research Institute, Moshi, Kilimanjaro, Tanzania

Rationale:
Paper maps have nowadays been replaced by digital maps; thanks to the recent technologies called Geographic Information Systems (GIS). Most major agricultural research stations in Tanzania have adopted GIS. TaCRI was late to come on board because, historically, it had never had a cartographic unit. Collaboration with TARI-Mlingano in 2008/09 enabled the establishment of a mini-GIS unit at Lyamungu. Its task was to develop digital maps of the TaCRI Lyamungu estate, some of whose results are discussed in this paper.

Methods:
A non-georeferenced paper map developed in 1934 was scanned, carefully scrutinized and a total of 8 control points selected, whose x-y coordinates were taken with a GPS tool. They were loaded into Excel spreadsheet, properly formatted and saved as a GIS-compatible .csv file. The file was opened in ArcMap 10.7.1, whereby the image and the point shapefile were properly aligned with residual ≤ 0.15. Several empty polygon and line shapefiles were created on ArcCatalog, each digitized onscreen and saved separately as a complete map layer in ArcMap, including "boundary" and "field" polygon shapefiles, the latter divided into seven different land use categories. Soil fertility data (pH, CEC, OC and available P) from 113 georeferenced points within the estate were geocoded, loaded into ArcMap, interpolated in turns using the IDW algorithm and clipped on basis of the boundary shapefile.

Results:
The resultant was the first ever digital map of TaCRI Lyamungu estate. It has five generic shapefile layers - boundary, rivers, roads, settlements and fields, and one specific shapefile "soildata". Commercial, semi-commercial and trial fields were largest in extent, followed by forests and germplasm collection. Whereas the map for CEC showed irregular trends, those for pH, OC and available P unveiled interesting ones, including hotspot areas for setting out liming, ISFM and P response trials respectively.

Conclusions & Perspectives:
This work has formally introduced TaCRI to the GIS world – an important step as GIS is becoming ubiquitous in global research, planning and problem solving. The work has also proved that even the non-georeferenced paper maps in our archives are still useful as long as you can georeference key points with a GPS and have facilities for onscreen digitization.

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Response of improved Arabica varieties in Tanzania to secondary macronutrients and micronutrients

Maro Godsteven (godsteven.maro@tacri.org), Mbwambo Suzana, Monyo Harrison, Nkya Emmanuel, Mosi Epafra

Good Agricultural Practices Research, Tanzania Coffee Research Institute, Moshi, Kilimanjaro, Tanzania

Rationale:
The advent of 19 improved Arabica varieties resistant to CBD and CLR would naturally preclude the application of copper-based fungicides; if not for the perceived tonic effect, described by Van der Vossen and Browning (1978). Furthermore, coffee soils in Tanzania have recently shown a general Sulphur deficiency, calling for a NPKS formulation (Cordingley, 2010). A study was conducted to assess the effect of copper, sulphur and a ready-made cocktail "Polyfeed" on leaf retention, plant characteristics and yield of selected new varieties.

Methods:
Two trials were established at Lyamungu onstation and a nearby APK estate in 2015 and 2017 respectively. They followed a split plot design in randomized complete blocks (three replications). Varieties KP423 (check), TaCRI-6F (new compact) and KP423-1 (new tall) were the main factors and the nutrient cocktails (60g copper oxychloride - Cobox as foliar spray, 60g Cobox and 75g Polyfeed as foliar spray, 75g Polyfeed alone, 50g of SA 21%N applied to the soil, and an untreated control) were sub factors. All plots were equally treated with NPK 20:10:10 at 150g per tree before application of the cocktails. The trials were run for 3 years with leaf retention, growth characteristics and yield data captured. Data were exposed to ANOVA using the COSTAT software; with means separated by Tukey's HSD method at 0.05 significance level.

Results:
Leaf retention was not significant ($p > 0.05$), implying that the number of active leaves, and therefore photosynthetic capacity, is not affected by the added cocktails as long as the major nutrients are optimally supplied. Varieties had a deceasing significance trend in yield over the years, implying, probably, that yields of different varieties tend to normalize with age. The treatment cocktails onstation had an increasing significance trend in yield, whereas they were consistently very highly significant ($p<0.001$) onfarm.

Conclusions & Perspectives:
The dominance of copper oxychloride and SA in the first two rankings partly confirms the tonic effect of copper application in coffee and the soil's responsiveness to sulphur. This paper therefore encourage the use of NPKS formulations, and recommend a twice-yearly application of 60g copper oxychloride even for the improved varieties.

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Unexpected coffee varietal diversity in Haitian coffee agroforestry systems

Millet Claude Patrick[1] (claudepatrickmillet@gmail.com), Allinne Clémentine[2], Vi Tram[1], Marraccini Pierre[1], Verleysen Lauren[3], Ruttink Tom[3, 4], Zhang Dapeng[5], Solano-Sanchéz William[6], Tranchant Christine[1], Jeune Wesly[7], Poncet Valérie[1]

[1] *UMR DIADE, IRD, Montpellier, France* ; [2] *UMR ABSys, CIRAD, Montpellier, France* ; [3] *ILVO, Melle, Belgium* ; [4] *University of Ghent, Ghent, Belgium* ; [5] *USDA, Beltsville, MD, USA* ; [6] *CATIE, Turrialba, Costa Rica* ; [7] *Faculté des Sciences de l'Agriculture et de l'Environnement, Université de Quisqueya, Port-au-Prince, Haiti*

Rationale:
Though they face significant challenges, Haitian Coffee (*Coffea arabica*) Agroforestry systems are important providers of several ecosystem services, and generate incomes for around 200.000 coffee farming families. To ensure their long-term sustainability, enhancing the value of their genetic heritage is a major lever. However, little is known about the diversity of coffee trees growing in these systems. Several varieties are often grown together and allowed to mix, with recruitment from the seed bank common. In light of this, there is a need to characterize Haitian coffee diversity to help inform strategies for revitalizing this sector.

Methods:
In this study, we sampled coffee trees from 28 diverse farms in historically important coffee growing regions of Northern and Southern Haiti. We performed targeted multiplex amplicon sequencing and KASP-genotyping of highly polymorphic markers in *C. arabica* on our samples, as well as a large panel of Ethiopian and commercial accessions from international collections. These reference accessions allowed us to assign Haitian trees to varietal groups.

Results:
Our analyses revealed that Haitian farms hold a high level of genetic diversity, higher in fact than many farmers realize, and comparable to that held in germplasm collections. Genetic sStructure analyses revealed the presence of main clusters related to the Typica, Bourbon, Catimor and Kent groups respectively, one which was not represented in our reference accession panel, as well as several admixed individuals. While diversified farms were found across our study area, we also identified monovarietal farms where only the traditional Typica coffee trees grow.

Conclusions & Perspectives:
This study is, to our knowledge, the first to have genetically characterize Haitian *C. arabica* and shows that some Haitian Coffee Agrosystems are repositories of historical, widely-abandoned varieties while others are generators of new diversity through genetic mixing. Future study of the latter may reveal adaptive potential and suggest ways of mobilizing this diversity to respond to challenges faced by farmers.

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Qualitative land suitability assessment for Arabica coffee in the TaCRILyamungu Estate, Tanzania

Monyo Harrison (harrison.monyo@tacri.org), Maro Godsteven, Mbwambo Suzana, Mosi Epafra

Good Agricultural Practices, Tanzania Coffee Research Institute, Moshi, Kilimanjaro, Tanzania

Rationale:
The Lyamungu Estate was established in 1934 and taken over by TaCRI in 2001. No record of land suitability information for coffee in the estate is available, even though it has hosted many coffee field trials. The aim of this study was therefore to assess the quality of land in general and soil fertility in particular, thus filling the information gap.

Methods:
A total of 113 randomly located survey sites across the estate had their soil samples analyzed for routine soil fertility parameters. Land evaluation (qualitative, parametric method) was done, with climatic data adopted from a local weather station while other land characteristics (slope, drainage and soil depth) taken from the field. Laboratory data included ACEC, SBC, pH and OC. The square root method was used to compute the climatic index (Ic), whose rating (Rc) was calculated and used in the determination of the land suitability index (IL). Land suitability was rated as S1(very suitable), S2 (moderately suitable), S3 (marginally suitable) and N (unsuitable) for the respective IL ranges of 100-75, 50-74, 25-49 and 0-24.

Results:
Of the 113 sites evaluated, the categories S2 and S3 shared 44 sites each (38.94%) implying that the bulk of the land (77.88%) is moderately to marginally suitable for Arabica coffee, with limitations being soil pH and organic matter content. The category S1 (very suitable) featured in 22 sites, which is 19.5%. The category N (unsuitable) featured in only three sites, which is 2.65% and therefore, negligible.

Conclusions & Perspectives:
The implication of the above findings is that the land at TaCRI Lyamungu Estate is suitable to marginally suitable for Arabica coffee. The limitations of low pH and low organic matter content can be mitigated by careful liming and mulching/manuring respectively. With the changing climate and soil fertility statuses, we recommend such an activity to be routinely done once every ten years.

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Adaptation Strategies for the adverse effects of climate disruptions on coffee trees productivity in Cameroon

Mouen Bedimo Joseph (josephmouen@yahoo.fr), Ndoumbe Nkeng Michel

Consulting firm in Agricultural Research and Advices (CERCA), Yaoundé, Cameroon

Rationale:
The decline of Cameroon coffee production is increasingly designated as one of the negative consequences of climate change on plants development. The purpose of this study was to contribute to improving the productivity of coffee trees, in their production areas, in Cameroon.
Methods:
Thus, two hundred and eighty (280) trees, located in three different agro-ecological zones, were monitored for five consecutive years (2014-2018). Meteorological data (rainfall, minimal and maximal temperatures) and biological data (number of diseases and punctured berries) were also systematically collected at each site.
Results:
Data analysis highlighted three classes of unstable meteorological profiles that reflect the non-recurrence of climatic events on the study sites. Multiple logistic regression analysis showed that the incidence of Arabica coffee berry disease increases with the quantity of rainfall and the number of rainy days. This increase rather induces a decrease in the attack rate of berry borer on the Robusta coffee trees.
Conclusion & Perspectives:
The results obtained made it possible to identify, by elucidating their respective roles, the climatic variables that have an effect on the productivity of coffee trees. They have also led, for the first time, to the conceptualization of innovative technical processes, which can reduce the harmful effects of climatic disturbances on coffee crops.

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Coffee husk supplementation for optimized growth and postharvest quality of *Ipomea reptans* Poir

Mubarak Aidilla[1, 2] (aidilla@umt.edu.my), Safalisam Maizatul Najjuwa[1], Norasmadi Iman Nur Sabrina[1], Zulkipli Nurain Nabilah[1], Mohd Shah Ramisah[1]

[1] *Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, 21030, Kuala Nerus, Terengganu, Malaysia* ; [2] *Food Security Research Cluster, Universiti Malaysia Terengganu, 21030, Kuala Nerus, Terengganu, Malaysia*

Rationale:
Coffee processing produces various by-products which include coffee husk. The reutilization of this agricultural waste is valuable due to its bioactive components. *Ipomea reptans* Poir, locally known as kangkong darat is an important and commonly grown green leafy vegetable in Southeast Asia. Coffee husk (CH) has been used for improvement of soil, but has yet to be tested as a supplement towards growing of *Ipomea reptans* Poir. This study therefore explored the potential of CH as a supplement incorporated into commercial NPK fertilizer towards optimizing growth and postharvest quality of *Ipomea reptans* Poir.
Methods:
Varied ratio of CH with commercial NPK fertilizer (50% NPK+ 50% CH, 20% NPK+80% CH and 100% CH) was tested on *Ipomea reptans* Poir grown in polybags, and compared to the ones applied with 100% commercial NPK only. Selected measures of plant growth and postharvest quality were determined.
Results:
The application of 50% NPK + 50% CH was found to significantly improved the plant height, stem diameter, number of leaves, weight of plant and greenness of the leaves ($p<0.05$) when compared to the other ratio of CH application. Postharvest quality of the plant was similar to the application of 100% NPK. The application of 100% CH showed a lower quality of the plant when compared to the other treatments ($p<0.05$).
Conclusions & Perspectives:
This study reports a useful utilization of the coffee husk at a controlled amount (50:50 ratio with NPK fertilizer) for the growth of *Ipomea reptans* Poir. The reliance on NPK fertilizer can therefore be reduced and optimized production cost of *Ipomea reptans* Poir can be obtained. In addition, the utilization of coffee husk helps to regenerate the worth of this coffee processing residue, aids in waste management and therefore creates a sustainable agricultural practice.

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Revitalization of coffee in Kenya: support research development and technology transfer

Mugo Harrison[1] (mugohmu@yahoo.com), Minai James[2], Kimeu Emmanuel[3]

[1] *Coffee Research Institute - Entomology Department, Kenya Agricultural and Livestock Research Organization, Ruiru, Kenya* ; [2] *Coffee Research Institute- Ressearch Liaison Department, Kenya Agricultural and Livestock Research Organization, Ruiru, Kenya* ; [3] *Coffee Research Institute- Kenya Coffee Ttraining College, Kenya Agricultural and Livestock Research Organization, Ruiru, Kenya*

Rationale:
The coffee subsector in Kenya is one of the major contributors to the Kenya's economy. It is a key contributor to foreign exchange earnings, family incomes, food security and employment to over five (5) million Kenyans. Kenya is renowned for some of the best mild Arabica coffees in the world, produced by both the smallholder and estate farmers. Over the years, the national coffee production has declined from 129, 0000 metric tonnes of clean coffee to an annual average of 40,000 metric tonnes, a decline of about 70%. To address the decline, the Government of Kenya developed and implemented a coffee revitalization program through Kenya Agricultural and Livestock Research Organization - Coffee Research Institute (KALRO - CRI).The goal of the program was to increase agricultural productivity and profitability to rural coffee smallholder farmers in Kenya. The program was piloted in eight (8) main coffee growing counties from the year 2021 to 2023 (two and half years).

Methods:
The Institute implemented the program by conducting several activities. These included a desktop review of existing technologies, capacity building of extension staff and agronomists, mass propagation of coffee planting materials, soil sampling and analysis, and pests' survey in the piloted counties.

Results:
The Institute inventoried 108 coffee Technologies, Innovations and management practices (TIMPS) with 75 of them ready for upscaling. The Institute also trained 161 County agricultural extension staff and Cooperative Societies' Agronomists on coffee agronomic practices who were subsequently to train the coffee Lead farmers in the counties. A total of 7,045 kgs of coffee seed (equivalent to 21 million seedlings) were produced for the farmers to expand their plantations. Coffee farmers' soil samples totaling 2,724 were analyzed and three (3) county/regional specific fertilizer formulations developed. The pests survey realized three (3) insect pests; Green scales (*Coccus alpinus*), Yellow headed borer (*Dirphya nigricornis*) and White borers (*Anthores leuconotus*), and two (2) diseases; Coffee Berry Disease (*Colletotrichum kahawae*) and Coffee Leaf Rust (*Hemileia vastatrix*) as key in all the counties surveyed with overall infestation and infection above 30%.

Conclusions & Perspective:
The program targeted over 100, 000 coffee farmers with the aim of increasing coffee productivity from an average of 2 kgs to 10 kgs per tree. Arising from the success of implementing the national coffee revitalization program, KALRO-CRI is now ready to upscale the program from the piloted eight (8) counties to all the 32 coffee producing counties in Kenya.

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Empowering agricultural marketing coparative societies (AMCOS) to improve coffee productivity and production: case study of hai district in Tanzania

Mwakabuta Twisege Andrew[1] (twisemwakabuta@yahoo.com), Magesa Jeremia Marco[1], Kilambo Deusdedit[2]

[1] *Technology Transfer Training and Advocacy, Tanzania Coffee Research Institute, Moshi, Kilimanjaro, Tanzania* ; [2] *Crop Improvement, Tanzania Coffee Research Institute, Moshi, Kilimanjaro, Tanzania*

Rationale:
Recently there has been an increase in coffee productivity and production in Tanzania particular in Hai district in Kilimanjaro region. This is contributed by the use of improved coffee varieties and promotion of good agricultural practices (GAPs) implemented by Tanzania Coffee Research Institute (TaCRI). In Hai district, TaCRI is currently working with 25 coffee AMCOS with more than 6000 farmers by promoting the use of improved coffee varieties and application of GAPs to increase coffee productivity and production. Therefore this paper describes various interventions that have led to the increased coffee productivity and production in Hai district

Methods:
The case study was conducted in potential coffee growing wards in Hai district for the period of five (5) years from 2017/2018 to 2021/2022. Collected data from AMCOSs included number of trainings conducted, number of trained farmers, Training of Trainers (ToT), coffee grades and coffee prices. On the other hand, data collected from smallholder coffee growers were number of improved coffee seedlings distributed, seedlings survived and coffee production (kg) per year.

Results:
The result shows that, in areas where TaCRI interventions have been effective farmers who planted the improved varieties and adapted the application of GAPs have increased their yields and quality of coffee has improved on screen size of the bean from grade A and B to AA, A and PB leading to better market price and hence increasing farmers' income and livelihood. Current information shows that, in Hai district coffee production has increased from 831 to 962 tons after replanting 1.4 million of improved coffee seedlings together with conducting trainings to more than 970 coffee farmers who are AMCOS members and 198 AMCOS leaders (ToT).

Conclusions & Perspectives:
The use of improved coffee varieties as a substitute to local varieties through new farms establishment, farms rehabilitation, adoption of the GAPs and primary processing techniques given by TaCRI have improved coffee quality, productivity and production. So promotion and dissemination of appropriate and financially viable technologies to coffee farmers improves coffee quality, productivity and production.

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Impact of lime application on soilborne pests and diseases in acidic soils of coffee plantations in the Central Highlands in Vietnam

Nguyen Van Long[1, 2, 3] (s222117312@deakin.edu.au), Herrmann Laetitia[1, 3], Le Dinh Thao[4], Nguyen Van Chung[4], Nguyen Van Liem[4], Brau Lambert[1, 5], Enez Aydin[1, 5], Venugopal Abhirami[1, 5], Lesueur Didier[1, 3, 6]

[1] *School of Life and Environmental Sciences, Deakin University, Melbourne, Victoria, Australia* ; [2] *Pepper Research and Development Center, Pleiku, Gia Lai, Vietnam* ; [3] *Common Microbial Biotechnology Platform (CMBP), International Center for Tropical Agriculture (CIAT), Ha Noi, Vietnam* ; [4] *Plant Protection Research Institute (PPRI), Ha Noi, Vietnam* ; [5] *Centre for Regional and Rural Futures (CeRRF), Deakin University, Melbourne, Victoria, Australia* ; [6] *CIRAD, Ha Noi, Vietnam*

Rationale:
Vietnam is the number one producer of Robusta coffee globally and there are approximately 650,000 ha of plantations concentrated in the Central Highlands. The expansion of coffee cultivation in recent years has been poorly managed in many cases and resulted in declining plant health, soil fertility (high soil acidification) and soil health, and increased pest and pathogen pressures. These factors are having detrimental impacts on coffee productivity and are potentially limiting access to high value markets. Around 300,000 ha of coffee plantations must be renewed and to date, 40% of the replanting operations failed due to the pressure of acidic soils and various soilborne pests and diseases (SBPDs) such as nematodes and *Fusarium* spp.

Methods:
Farm trials were conducted in Giai Lai Province on ten productive Robusta coffee plantations with two treatments (2.5 t ha-1 dolomite lime and a control with no lime) from September 2021 to September 2022. Soil pH was monitored on the monthly basis for each farm and after one year; soil physiochemical and biological properties and SBPDs were observed after one year lime application.

Results:
Lime applications increased soil pH by an average of 0.49 unit compared to control (70% of the farms responded positively to lime application). Additionally, lime application significantly enhanced ($P<0.05$) OM%, exchangeable K, Ca2+, Mg2+ by 16.70%, 26.48%, 100% and 243% respectively and decreased exchangeable Al3+ by 30.88% compared to control. On the other hand, no significant differences between both treatments were observed for available NH4+, NO3-, P and exchangeable Fe3+. AMF frequency and intensity were significantly enhanced by lime application compared to control (91.90% and 23.86% respectively for the limed plots and 79.40% and 18.42% for the control). Despite this, our results did not show any significant influence of liming on the populations of *Fusarium* spp., *Rhizoctonia* spp. and plant parasitic nematodes. Under controlled conditions, we determined that for an increase of one unit of pH in an acidic soil requires 25 tons of lime ha-1 which is not feasible for farmers.

Conclusions & Perspectives:
Other practices/alternatives must be investigated such as utilization of commercial bioinoculants containing beneficial microorganisms' antagonist of SBPDs or/and combined with agroecological practices based on the utilization of nematicide legumes such as *Crotalaria pallida* which in addition of being capable to symbiotically fix atmospheric N, also releases nematicide metabolites (Pyrrolizidine alkaloids and monocrotaline) reducing the populations of plant parasitic nematodes.

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Coffee production and farm management practices in Nigeria and selected African countries

Oladokun Yetunde Olasimbo Mary (yetunde.oladokun@gmail.com), Lawal Justina Oluyemisi, Agulanna Foluso Temitope

Economics and Extension, Cocoa Research Institute of Nigeria, Ibadan, Oyo, Nigeria

Rationale:
Coffee is one of the major cash crops produced in Nigeria but recently its production has dwindled when compared with crops like Cocoa. In Nigeria, the coffee value chain is reported to employ nine million farmers, making it one of the largest employers of labour [1]. Poor farm management practices, inadequate mechanization, poor funding and climate change among other factors inhibit the production of coffee in Nigeria. Depending on the varieties cultivated, factors like climatic weather and soil conditions greatly impact on coffee production.This study thus compared the production of coffee in Nigeria with six top producers in Africa.

Methods:
Data on area of land cultivated (hectares), yield (kg/ha) and production in tonnes were used from FAO 2020 (Food and Agricultural Organisation) Secondary data. Seven countries with the highest green coffee production in Africa Ethiopia, Uganda, Cote d'Ivoire, Madagascar, Kenya, Sierra Leone and Nigeria were selected. Fifty-eight years of green coffee production were presented in the data (1961-2018). Frequencies, percentages and charts were used for analysis in this study.

Results:
The average land cultivated over the years for the seven countries were 435011.3ha, 256242.3 ha; 760188.8 ha; 209826.5; 127496.8; 10661.81 and 4530.19 hectares respectively. The average yield were 8379.02hg/ha, 20917.9hg/ha, 2770.21hg/ha, 4033.40hg/ha, 12600.66hg/ha, 15593.31hg/ha and 8061.40hg/ha for Ethiopia, Uganda, Cote d'Ivoire, Madagascar, Kenya, Sierra Leone and Nigeria respectively. The average production in tonnes were 222414.9, 175601.2, 208208.5, 68873.97, 68054 .6, 17690.22 and 3035.67 for Ethiopia, Uganda, Cote d'Ivoire, Madagascar, Kenya, Sierra Leone and Nigeria. Farm management practices considered in these countries include removal of big shady trees, adoption of climate smart agricultural practices, appropriate processing techniques, sustainable land management practices and quality extension services. Nigeria ranked the least in the area of land, yield and production because of lack of appropriate farm management practices.

Conclusions & Perspectives:
Nigeria ranked the least in the area of land, yield and production because of lack of appropriate farm management practices. This study hereby recommends that the right policies be put in place to enhance appropriate farm management practices for increased coffee production, domestic consumption and export.

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Nutrient Management in Coffee - Influences on Nitrogen Use Efficiency and Carbon Footprint

Ramirez-Builes Victor Hugo (victor.ramirez@yara.com)

Institute for Plant Nutrition ann Enviroment, Yara International, Dülmen, NRW, Germany

Rationale:
Improving the nitrogen use efficiency (NUE) and reducing the carbon footprint (CFP) in coffee are key challenges for coffee production worldwide and represent the main action points regarding regenerative and climate-neutral crop production agriculture. The objective of this work was to evaluate at the field level in long-term trials the influence of several nutrient management practices on NUE and CFP.

Methods:
During the period 2014 to 2021, five long-term trials in two coffee species were conducted in four countries: **Trial 1** in Vietnam in Robusta, **trial 2** in Ivory Coast in Robusta, **trial 3** in Brazil in Arabica, and **trials 4 and 5**in Colombia in Arabica. In trials 1, 3, 4, and 5 we compared current farmer practices (NPK fertilization based on Urea) to treatments with more balanced nutrition (increased share of nitrate-N and application of Ca, Mg, and micro-nutrients). N was applied at a similar rate in the farmer and in the balanced fertilization treatment. In trial 2, treatments with balanced nutrition and increasing N rates were compared to a treatment reflecting farmer practices with N applied at a low rate. NUE and CFP were estimated after 4 to 6 years of harvest in the trial.

Results:
When a farmer uses low N fertilizer rates but includes other essential nutrients in the fertilizer program, the NUE increases 2,8 times from 9,19 to 25,52 kg coffee.kg-1N (**trial 2**). If the N rate increases from 100 to 200 kg N.ha-1in a fully balanced fertilizer program (all other essential nutrients applied), the NUE improves by 46% from 9,19 to 13,50 kg coffee.kg-1 N. When a farmer replaces Urea with a nitrate-based fertilizer in the same balanced fertilizer program, the NUE rises by 14% from 3,67 to 4,18 kg coffee.kg-1 N (**trial 3**). Increasing the share of Nitrate-N up to 75% of total N in a balanced fertilizer program including other macro- and micronutrients improves the NUE by 2,9 times from 1,32 to 3,78 (**trial 4**). The results also reveal that a replacement of the farmer program based on Urea with a nitrate based program can reduce the CFP by 7% to 19% (**trials 1,3, and 5**).

Conclusions & Perspectives:
Coffee farmers can increase coffee yields, reduce the CFP, and increase NUE if they improve nutrient management practices by changing N sources and by balancing NPK inputs with other essential nutrients like Ca, Mg, B, and Zn.

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Effect of shading on performances of new Arabica coffee varieties in Northwest Vietnam

Rigal Clement[1] (clement.rigal@cirad.fr), Nguyen Chang[2], Hoang Thao[2], Nguyen Vân[2], Sarzynski Thuan[3], Marraccini Pierre[3], Vaast Philippe[4], Etienne Hervé[3]

[1] *UMR Absys, CIRAD / ICRAF, Montpellier, France* ; [2] *NOMAFSI, Mai Son, Vietnam* ; [3] *UMR Diade, CIRAD, Montpellier, France* ; [4] *UMR Eco&Sols, CIRAD, Montpellier, France*

Rationale:
Coffee-agroforestry systems are known to provide numerous ecosystem services and socio-economic benefits compared to monoculture systems. However, most high-yielding coffee varieties have been bred and selected for optimal performances under full sun conditions, and perform poorly when intercropped with shade trees. Consequently, there is a need to select and test coffee varieties adapted to shaded environment to support the development of sustainable agroforestry systems more adapted to climate change. In line with this objective, we studied the performances of 4 modern Arabica coffee varieties under a shade gradient in Northwest Vietnam.

Methods:
In 2019, coffee trees belonging to 4 varieties (Catimor, Marsellesa, Starmaya and Centroamericano) were planted in a random block design in 2 trials located in Son La Province, Vietnam. They were intercropped with various fruit trees including macadamia and plums. The present study was conducted in 2022 when coffee trees were already productive. Bud, flower, and fruit counting were carried out in 6 rounds from February to September 2022. Harvest was monitored between October 2022 and January 2023. Shade levels throughout the year were estimated using ShadeMotion to create 3D models of both trials.

Results:
Under low (<15%) and medium (15-30%) shade conditions, Starmaya and Centroamericano exhibited better performances than Catimor and Marsellesa. They had more flowers, more fruits and ultimately higher yields. Additionally, they displayed stable yields across shade levels ranging from 0 to 30%. Conversely, Marsellesa yields were negatively correlated with shade levels, even under low shade conditions. Under high shade levels (>30%), all 4 varieties experienced a sharp yield decline.

Conclusions & Perspectives:
The newly introduced Starmaya and Centroamericano hybrid varieties demonstrate higher productivity compared to the widely cultivated Catimor pure line variety. More importantly, this higher agronomic performance extends up to medium shade levels (30%). Promoting these hybrid varieties could therefore facilitate the adoption of agroforestry in the study area, providing that shade levels do not exceed 30%. This shade threshold should be considered in the design of agroforestry models to ensure optimal coffee yields. Conversely, Marsellesa appears to be the variety least suited to shade conditions and should only be recommended for monoculture systems.

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Organic coffee associated with shrub plants provides increased productivity and grain size

Santoro Patricia Helena[1] (patriciasantoro@idr.pr.gov.br), Morais Heverly[1], Machado Alessandra Helena Ramires[2], Furlanetto Thiago Luiz Ragugnetti[2], Favaro Gabriel[1]

[1] *Rural Development Institute of Parana – IAPAR/EMATER, Londrina, Parana, Brazil* ; [2] *State University of Londrina, Londrina, Parana, Brazil*

Rationale:
The lack of appropriate management in the production of organic coffees can lead to decrease the productivity. In this study was evaluated assesses the development, productivity and granulometry of coffee intercropped with differents shrub plants in an organic production system.
Methods:
The experiment was carried out in Paraná, Brazil (24º27 'S and 53º25' O) with the cultivar IPR 107 (*Coffea arabica*), in spacing of 3.0×0.7m. The treatments were: coffee in monoculture and coffees associated with *Leucaena leucocephala*, *Ricinus communis*, *Moringa oleifera*, *Tephrosia purpurea* and *Cajanus cajan,* separately, with four replications per treatment, in 15.0×9.0 m plots. The shrub species were sown in double rows in the center of between rows of coffee, with 30 cm between rows and 20 cm between plants. When they reached an approximate height of 2.0 m, the shrub plants were pruned at a height of 50 cm from the soil and the branches were left in between coffee lines. After four years of conducting the experiment, coffee development, productivity and granulometry were evaluated.
Results:
The coffees associated with *M. oleifera* and *R. communis* presented larger plants, with 1.53 and 1.30 m in height, respectively. The smallest plants were coffee in monoculture and coffee with *C. cajan*, both less than 1.0 m high. The highest productivity of processed grains was for coffee associated with *R communis* with 3.058,8 kg/ha, followed by coffee with *L. leucocephala*, *T. purpurea*and *M. oleifera*, which ranged from 1.829,4 to 2.126,4 kg/ha. The lowest productivity were in monoculture coffee and coffee with *C. cajan*, which did not differ from each other with 1.099,9 and 1.386,6 kg/ha, respectively. Regarding granulometry the percentage of beans retained in the sieve 16 and above was above 86% in coffees associated with shrub species, which were superior to coffee in monoculture, with only 68%.
Conclusion & Perspectives:
The use of shrub plants associated with coffee is a viable practice in the production of organic coffee because it provides better plant development and a significant increase in productivity with larger beans that means better value on market. It is important to highlight that this practice is not limited to organic, but can also be used in the production of conventional coffees, as a strategy to rationalize the use of inputs.

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Effect of genotype and climate on the agronomic performance of 3 genotypes of Coffea Arabica

Sarzynski Thuan[1] (thuan.sarzynski@ecomtrading.com), Marraccini Pierre[2], Vaast Philippe[3], Nguyen Chang[4], Nguyen Hung[4], Nguyen Quyen[5], Nguyen Hai[5], Etienne Herve[6], Rigal Clement[7]

[1] *DIADE, CIRAD, Ho chi minh, Vietnam* ; [2] *DIADE, CIRAD, Kampala, Uganda* ; [3] *DIADE, CIRAD, Montpellier, France* ; [4] *NOMAFSI, Son La, Vietnam* ; [5] *NOMAFSI, Phu Tho, Vietnam* ; [6] *DIADE, CIRAD, Montpellier, Vietnam* ; [7] *Absys, CIRAD, Hanoi, Vietnam*

Rationale:
Coffee provides a livelihood for over 12 million households in tropical countries such as Brazil, Vietnam, Colombia and Indonesia. Climate change leads to increased average temperatures and changes in rain patterns across the globe, which influences plant productivity. As for many crops, *Coffea arabica*, is sensitive to environmental changes caused by climate change. Coffee plant breeding programs have produced vigorous coffee genotypes with higher yield however, the effect of climate change on these genotypes have never been investigated.

Methods:
The effects of genotype and climate on the agronomical performance of *Coffea arabica* were studied using nine trials covering an altitudinal gradient [600–1100 m above sea level (m.a.s.l.)] with three genotypes of *Coffea arabica* in the northwest mountainous region of Vietnam. The impacts of the climatic conditions on agronomical traits were assessed.

Results:
Genotype had a significant effect on height, branch length, diameter, nodes per branch. Catimor was less vigorous than F1-hybrids and have lower height, branch length, trunk diameter and number of nodes. The environment effect was significant for the fruit bean ratio, height, diameter, orthonodes and cumulated yield. Height, diameter was significantly affected by temperature but not by soil water content. Cumulated yield and fruit bean ratio were significantly affected by temperature and soil water content. Due of a very low application of NPK, fertilization rate did not affect agronomic performance.

Conclusions & Perspectives:
This study of the agronomic performance of 3 genotypes of *Coffea arabica* in Northwest of Vietnam highlights the higher vigor of the new varieties compared to the Catimor. Yield was significantly affected by temperature and soil water content, forecasting future struggles of *C.arabica* with climate change in the region.

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Centralized Directional System for Reducing Ground Losses in Mechanized Coffee Harvesters

Oliveira e Silva Felipe[1] (felipe.oliveira@ufla.br), Moreira da Silva Fábio[2], Santos Marques Leomar[3]

[1] *Department of Automatics, Federal University of Lavras, Lavras, MG, Brazil* ; [2] *Department of Agricultural Engineering, Federal University of Lavras, Lavras, Brazil* ; [3] *Inovação em Mecanização Agrícola CEIFA Ltda, Lavras, Brazil*

Rationale:
Mechanized coffee harvesting is based on the principle of vibration, according to which rods intersperse the coffee tree canopy, stripping the fruit. Of all the fruits that are stripped, about 15 to 25% do not reach bulk carriers, consisting of the so-called Ground Losses (GL). The largest volume of such losses occurs in the harvester blades, and can increase even more due to the decentralized guidance of the harvester w.r.t. the planting line (7 to 15% of the fruits that are stripped are lost in this way). This work summarizes the development and validation of a centralized directional system, for self-propelled coffee harvesters, capable of visually guiding the operator, regarding the misalignment condition of the machine w.r.t. the planting line, and consequently, decrease coffee GL.

Methods:
To identify the off-center condition of the harvester, pairs of precision angular sensors were installed directly under the harvester blades of the machine, both at the front (M1 assembly) and at the rear (M2 assembly). In order to evaluate the influence of each assembly in determining the harvester's decentralization condition, different statistical treatments were established (ground-truth treatment GT and treatments T1 to T4), which were defined based on different percentages of sensitivity, attributed to each assembly. For real-time processing and indication of the harvester's decentralization condition w.r.t. the central planting line, a processing unit was developed, equipped with LED bars. To validate the system, trials were carried out on coffee crops of the "Mundo Novo" cultivar, 7 years old, planted at 3.5 x 0.75 m spacing. The trials were carried out at an operating speed of 1000 m/h, with 4 replications per treatment, and plots of at least 20 plants.

Results:
Treatment / M1 sensitivity (%) /M2 sensitivity (%) / Average GL (%)*
GT / 0 / 0 / 12,6[a]
T1 / 80 / 20 / 13,9[a]
T2 / 100 / 0 / 13,7[a]
T3 / 20 / 80 / 11,4[a]
T4 / 0 / 100 / 8,3[b]
*Comparison of means using the Scott-Knott test, with a significance level of 5%. Values with the same letter do not differ significantly.

Conclusions & Perspectives:
Compared to the GT treatment, the T4 treatment (0% for M1 and 100% for M2) resulted in a reduction in GL of approximately 50%, which is significant. These results proved that the main need for centering the harvester does not reside in its front part, as traditionally defended by conventional operational practice, but instead, in its rear part.

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Postharvest of *Coffea canephora* var. conilon: an analytical approach to the study of different processing methods

Bárbara Zani Agnoletti[1] (barbara.za@hotmail.com), Aldemar Polonini Moreli[2], Lucas Louzada Pereira[2], Emanuele Catarina Da Silva Oliveira[2], Paulo Roberto Filgueiras[1]

[1] *Chemistry, Federal University of Espírito Santo (UFES), Vitória, Espírito Santo, Brazil* ; [2] *Federal Institute of Espírito Santo (IFES), Venda Nova do Imigrante, Espírito Santo, Brazil*

Rationale:
Fermentation of *C. canephora* is an alternative for enhancing its quality, as biochemical processes that occur can induce changes in the chemical and sensory characteristics of coffee.[1] In this study, an analytical approach combining Fourier transform mid-infrared spectroscopy (FTIR) and principal component analysis (PCA) was used to assess the influence of different postharvest methods on the chemical profile of coffee produced in 2021 and 2022.

Methods:
Conilon coffee fruits harvested in the North/Northwest region of the State of Espírito Santo, Brazil, in 2021 and 2022, underwent five postharvest treatments (T): washed (T1), dry-fermentation (T2), yeast fermentation (T3), natural fermentation (T4), and natural control (T5). T1, T2, T3, and T4 were fermented for 36 hours, while T5 was not fermented. FTIR spectra were acquired from roasted coffees,[2] pre-processed using multiplicative scatter correction (MSC), mean-centered, and analyzed using PCA.

Results:
The first two principal components (PC1 and PC2) of the PCA model accounted for 92.22% of the total variance. Coffees produced in 2021 were concentrated in the negative direction of PC1, while those produced in 2022 were located in the positive direction of PC2. PCA Loadings revealed the spectral regions contributing to the separation by year: 1650-1550 cm^{-1}, associated with caffeine, and other compounds that absorb between 1400 and 650 cm^{-1}.[3] Regarding the treatments, T1, T2, and T3 clustered in the positive direction of PC2, whereas T4 and T5 were positioned in the negative direction of the same component. This happened in two years. The regions linked to the absorption of the OH group from water or chlorogenic acids (3500-3000 cm^{-1}) and caffeine (1650-1550 cm^{-1}) [3] played a role in distinguishing these treatments.

Conclusions & Perspectives:
The findings suggest that the postharvest methods employed contribute to the biochemical modulation of *C. canephora* var. conilon coffee, as the chemical profiles remained consistent regardless of the year, being influenced only by the method used. The caffeine content in *C. canephora* can vary between harvests.

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Study of chemical variation in carbonic maceration of *Coffea canephora* var. Conilon as a function of fermentation time using infrared microscopy

dos Santos Gomes Willian[1] (gwill.bio@gmail.com), Louzada Pereira Lucas[2], da Silva Oliveira Emanuele Catarina[2], Pereira de Araújo Sarah Cristina[2], Moreira Réboli da Silva Isabelli[2], Cardoso Gonçalves Leonardo[2], Partelli Fábio Luiz[3]

[1] *Coffee Design Group, Universidade Federal do Espírito Santo, Alegre, Espírito Santo, Brazil* ; [2] *Coffee Design Group, Instituto Federal do Espírito Santo, Venda Nova do Imigrante, Espírito Santo, Brazil* ; [3] *Department of Agrarian and Biological Sciences, Universidade Federal do Espírito Santo, São Mateus, Espírito Santo, Brazil*

Rationale:
The duration of fermentation during carbonic maceration (CM) in coffee is a crucial factor, which can affect the chemical compounds present in coffee beans. With the aim of investigating the chemical variation of the CM of *C. canephora*as a function of fermentation time, this study used infrared microscopy as an analytical technique.

Methods:
Fruits of the species *C. canephora* var. Conilon were submitted to CM [1] at 18°C, during 24, 48, 72, 96 and 120 hours of fermentation. Infrared spectra were obtained according to the methodology followed by Gomes et al., [2].

Results:
Principal component analysis was able to identify the separation of fermentation times. The separation of the times of 24 h and 96 h concentrated on the negative axis and the times of 48, 72 and 120 h on the positive axis of PC1 (Figure 1).

Conclusions & Perspectives:
The results suggest differences in the composition of the chemical classes as a function of the duration of fermentation time. Thus, identifying compounds and correlating them with the quality of the beverage will be important for the adoption of adequate parameters for MC in *C. canephora*.

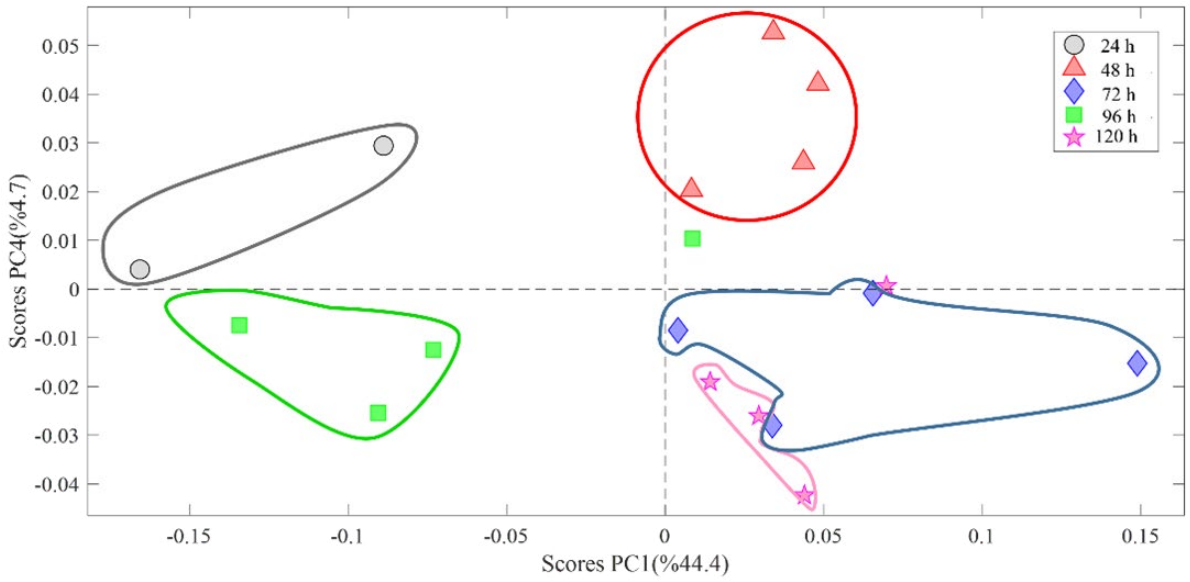

Figure 1 PCA classified by fermentation time.

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Coffees resulting of a controlled fermentation (with selected yeast) present a better freshness and quality during storage

Duez Camille[1] (cduez@lallemand.com), Poirot Pierre[2]

[1] *Lallemand, Blagnac, Autre, France* ; [2] *Lallemand, Blagnac, France*

Rationale:
Selected yeasts for coffee fermentation have been more and more brought forward for their different positive properties : high pectinolytic activities (polygalacturonase – pectin lyase – pectin methylesterase) to degrade coffee mucilage (C. Pereira Silva et al. 2013), improving the final quality in the cup by producing different aromatic compounds – acetaldehyde, ethyl acetate, isoamyl acetate that can diffuse into the beans remain after drying and storage (Hadj Salem et al., 2020). On another note, it is also known that green coffee quality degrades during storage, losing in SCA score but also in aromatic compounds (Zarebska et al. 2022). However, it has been noticed from several producers using Lalcafé™ yeasts selected for coffee processing, that the green coffees resulting from inoculated fermentation were stabilizing and even improving over time.

Methods:
We collected coffee samples from several field trials – Nicaragua, Brazil – that have undergone different processes of fermentation. For all batches, we fermented coffee with and without Lalcafé™ starters and received the coffees about 3 months after. We monitor different sensory attributes through a ranking test and ask a minimum of 10 panelists for their ranking in preference and/or on perceived freshness, the test was done every 3 months for 9 months.

Results:
For the Nicaraguan coffees in submerged trials, the results show that the control coffee started with 41% of preference decreasing to 25% over one year of storage. For the natural, the results were also showing better quality for the inoculated coffees : the control started being evaluated as the freshest and only 10% over one year of storage. Looking at the Brazilian coffees, the SCA cupping score went from 78.25 to 83 in continuous drying and from 82.1 to 83.9 in intermittent drying after 18 months of storage when the coffee was inoculated.

Conclusions & Perspectives:
Overall, several lots of fermentation trials that we monitored showed us a positive impact of controlled fermentation through inoculation with selected yeast. The next steps would be to identify markers to follow over time as well as having more coffees monitored on a sensory ground. The green coffee being sold as commodity, it can end up to be stored for more than 2 years. These selected Lalcafé™ yeasts could help all players in the coffee value chain to leverage the coffee quality and therefore, price point.

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Fermentation of coffee cherries by selected yeast strains and its impact on the final aromatic quality of the coffee

Foncy-Penot Evelyne (s.henshall@fermentis.lesaffre.com)

Research and Developement, Fermentis, Lille, Default, France

Coffee cherries fermentation is a crucial step in the coffee beans processing that impacts the quality and flavours of the final product. The use of the most relevant microorganism(s) allows to produce coffee with unique flavour profiles that cannot be achieved through spontaneous fermentation with endogenous yeasts. The use of selected yeasts can help to standardize the fermentation process, which can lead to consistent flavour profiles across different batches of coffee. This is particularly important for coffee producers who want to maintain a certain level of quality in their products. Moreover, the use of yeasts can also help to reduce the risk of spoilage by undesirable microorganisms, which can lead to lower yields and inferior quality coffee.

The aim of this presentation is to screen a panel of yeasts and to select the best ones for the fermentation of the coffee beans based on their tolerance to stress during fermentation and on the complexity of their aromatic profiles.

Effectively, the environmental conditions of the coffee bean fermentation are very stressful due to the presence of some toxic compounds (caffein, …), some organic acids (acetic, lactic, quinic acids for example) or the high temperature that can be reached during the cultures. That is the reason why the first step was to define different synthetic culture media to mimic this environment and to evaluate and compare the growth of each starter in these stressful conditions. Then the second step was to perform fermentation trials in a coffee farm in Nicaragua to test the 12 most robust yeast strains selected in the real conditions. The trials were carried out on Marsellesa Arabica coffee, and a natural process was applied on all trials. The duration of the fermentation was fixed at 60h. Then the fermented coffee beans were put on African beds under sun in 5 to 10 cm layer. Humidity was verified daily until it reached 11% (w/w). After, the green coffees harvested were roasted and sensory analysis was performed by a Q-Grader following a protocol established by the Specialty Coffee Association of America (SCAA) to ensure consistency and accuracy in the evaluation process. Those trials yielded interesting results. While some strains showed great potential in terms of enhancing the flavour and aroma of the coffee, others demonstrated a more neutral aromatic profile. For some of them, sensory analysis described a complex cup, with very pleasant aromas of dry fruits, nuts, cocoa, and caramel.

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Effect of Extented Fermentation with Yeast Starter Culture on cup quality in Washed and Natural Processed Coffees in Huatusco Mexico

Subramanian Siva[1] (siva.subramanian@ofi.com), Fong Leonard[2], Sun Francis[3], Miguel Jose[4], Holcomb Byron[5]

[1] *Coffee Innovation, Olam Food Ingredients, Willowbrook, Illinois, USA* ; [2] *Coffee Innovation, Olam, Willowbrook, Illinois, USA* ; [3] *Coffee Innovation, Olam Food Ingredients, Willowbrook, Illnois, USA* ; [4] *Specialty Business Unit, Olam Food Ingredients, Puebla, Mexico* ; [5] *Specialty Business Unit, Olam Food Ingredients, Guatemala City, Guatemala*

Huatusco is a large coffee growing areas within Mexico's Veracruz region. Green coffee is typically produced using washed process in this region due to high rainfall during the coffee picking season. Fermentation time is 12-16 hours is used and mostly the fermentation is done using indigenous microbiome. Most of the coffee produced typically falls under SCA score of 80-82. We used a yeast starter cultures in both washed and natural processing conditions to study the effect on the cup quality and aroma fingerprint of these coffees. For the natural process, whole cherries were sprayed with a dispersion of *Saccharomyces cerevisiae* at 1 kg/MT of cherries and left to ferment for 48 hours in anaerobic conditions. For washed process, the coffee cherries were pulped and yeast culture was added to the fermentation tank at 1 kg per MT of wet parchment and fermentation was done under submerged conditions for 48 hours. The coffees were dried on patio and dry milled in standard conditions. The aroma fingerprint of the green and roasted coffees were determined using GC Mass Spectrometer. Coffees fermented with yeast cultures provide a varying range of alchohols and esters which can be used to modulate the aroma towards fruity, fermented, winey or rum flavor in coffees. SCA cup scores of 84-85 were obtained for the washed & natural coffees.

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Enhancing Living Income and Sustainability of Social Forestry through (PMO Kopi Nusantara) Ecosystem Design for Coffee Farmers in Indonesia

Akbar Sholahuddin (sholahuddinabr@gmail.com), Hartatri Diany Faila Sophia, Ramadhani Alvin Rizki

Socio Techno-Economy, Indonesian Coffee and Cocoa Research Institute, Jember, Indonesia

Rationale:
This research is scrutinizing and suggesting an ecosystem-based design method aimed at amplifying income and promoting sustainability within social forestry systems in Indonesia, with a distinct emphasis on coffee cultivators. Social forestry schemes are being executed in Indonesia to encourage community-centered forest management, enrich local living standards, and preserve biodiversity. Nevertheless, there is an imperative need to delve into inventive methodologies that are integrating ecosystem design principles to amplify the productivity and economic feasibility of coffee cultivation within the purview of social forestry.

Methods:
This research combines qualitative and quantitative methods and is being conducted in specific locations in Indonesia's coffee-producing districts. The study begins with a literature review to create a theoretical framework for ecosystem design and social forestry systems. Data is collected through surveys, interviews, and participatory workshops with coffee farmers, social forestry stakeholders, and experts. Quantitative analysis examines the economic feasibility and income potential of coffee cultivation in social forestry, considering production costs, market access, pricing, and the value chain dynamics. Qualitative analysis identifies barriers, opportunities, and local perceptions related to the implementation of ecosystem design and its impact on income and sustainability.

Results:
The research highlights the importance of a participatory approach involving coffee cultivators, social forestry stakeholders, and experts. By integrating ecological principles, market-oriented strategies, access to capital, and collaboration between various stakeholders, the framework aims to improve productivity, income generation, and environmental sustainability.

Conclusions & Perpective:
The conclusions of this model are profoundly affecting the farmer's income, the resilience of social forestry for carbon capture, and environmental well-being. The suggested framework in this research is integrating ecological principles, market-oriented strategies, access to capital, and involvement from governmental entities, the private sector, and the community. This integrative approach is purposed to heighten productivity, income generation, and assure environmental sustainability. Additionally, it is targeting the enhancement of coffee productivity and quality, the augmentation of farmers' capacity, ensuring capital availability, and increasing the value of the products embedded within this ecosystem.

Waking up coffee-producing Mexico with the boost of research and development

Arrieta Noel[1] (narrieta@sfbaycoffee.com), Bracamontes Andros[2], Mora Rodolfo[3], Roblero Elizabeth[3]

[1] *Rogers Family Company, San Jose, Costa Rica* ; [2] *Rogers Family Company, San Francisco, USA* ; [3] *Rogers Family Company, Chiapas, Mexico*

Rationale:
Today Mexico coffee production receives an important boost at the initiative mainly of private companies. Currently, national production exceeds 3.5 million quintals and it is estimated that before reaching the year 2030, Mexico will be placed together with Brazil, Colombia and Honduras as the countries with the highest production in America. The state of Chiapas is the main producer and contributes approximately 40% of the total Mexican volume followed by the states of Veracruz with 30% and Oaxaca with 13%. The agro-ecological conditions offered by the extreme south of Mexico are suitable for coffee production, however, like Central America, production is constantly threatened by pests, diseases and extreme weather conditions. After the crisis caused by the impact of coffee rust in Mexico and Central America, the Rogers Family Company raised the concern of determining which varieties of coffee can be planted in the region to renew plantations old and depleted by rust.

Methods:
In Tapachula, Chiapas since 2017 year a study area was established with 28 varieties of coffee. The objective was to periodically evaluate variables of vegetative development, incidence of pests and diseases, productive yield, cup quality to describe and finally recommend which genotypes are best adapted to this terroir.

Results:
In the preliminary results, varieties such as F1 hybrids, CR 95, ANACAFE 14, Ruirú 11 and Obatá show between 33 and 46% greater productive potential, precocity and clear tolerance to coffee rust, compared to the traditional varieties. In addition, a high cup quality potential was determined. According to the data obtained, it is ratified that there are coffee varieties that meet high agro-productive standards and with excellent adaptability to the agro-ecological conditions of southern Mexico to boost the activity and achieve sustainability and profitability of the producing families.

Conclusions & Perspectives:
The inclusion of new genotypes in coffee farms in Mexico has increased production yields by up to 50%. With additional advantages such as obtaining a very competitive flavor and aroma profile cup and different resistance to pest and diseases genetic sources.

Assessing labor and economic performances of coffee- and pepper-based cropping systems in Vietnam

Duong Benoit[1, 2] (benoit.duong@cirad.fr), Rigal Clément[1, 2], Anders Sven[3], Long Chau Thi Minh[4]

[1] *UMR ABSys, CIRAD, University of Montpellier, INRAE, SupAgro, Montpellier, France* ; [2] *World Agroforestry, Vietnam Office, Hanoi, Vietnam* ; [3] *Department of Resource Economics and Environmental Sociology, University of Alberta, Edmonton, Canada* ; [4] *Agriculture System Department, The Western Highlands Agriculture and Forestry Science Institute (WASI), Buon Ma Thuot, Vietnam*

Rationale:
Robusta coffee (*Coffea canephora*) and black pepper (*Piper nigrum*) are important cash crops grown in the Central Highlands (CH) of Vietnam, covering 710 and 270 thousand ha, respectively, and crucial to the livelihoods of CH's farmers (General Statistics Office 2022). Recently, farmers have begun diversifying their cropping systems. As a result, various systems can now be observed in the CH, ranging from monocultures to diversified cropping systems with coffee, pepper, and fruit trees. However, diversification impacts farmers' production costs and labor requirements (Phan et al. 2019). To better understand these impacts, the present study introduces early findings of a survey on labor and economic performances in CH's coffee-pepper-fruit tree systems.

Methods:
As part of the ACIAR-funded V-Scope project, a socioeconomic survey on 239 households in Dak Lak, Dak Nong, and Gia Lai provinces was conducted using stratified sampling to study labor and economic performances of coffee-pepper-fruit tree cropping systems at the plot level. Plots were categorized into six groups based on crop dominance: coffee or pepper monocultures[2], diversified plots dominated by coffee or pepper or fruit trees[3], and most diversified plots without a single dominant tree crop[1].

Results:
Early findings show significant differences in total labor demands, measured in man-days/ha: coffee systems require the least labor (147-148 man-days), followed by fruit-dominated and most diversified systems (183-195 man-days). In contrast, pepper systems display the highest labor demand (232-239 man-days). Harvesting is the most labor-intensive task, from 35% up to 68% of the total labor in coffee and pepper monoculture, respectively. Associated gross margins range from 77.8 (pepper monocultures) to 112.7 million VND/ha (coffee diversified). Family labor stands for 36 to 57% of total labor, while hired labor can represent up to 61% of the total labor (pepper monocultures). Finally, variations in return to labor are found, ranging from 0.48 (pepper monocultures) up to 0.92 million VND/day (coffee systems).

Conclusions & Perspectives:
As labor requirements emerge as a key factor in explaining farmers' decision-making, this research presents labor dynamics and overall profitability of coffee- and pepper-led cropping systems in the CH. Given the inherent volatility of commodity prices and the potential for shifts in labor wages, the profitability of these labor-intensive systems could be significantly affected. The results seek to provide valuable insights for optimizing agricultural practices and enhancing the efficiency and sustainability of smallholder coffee- and pepper-based farming systems.

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The Economic Values of Coffea arabica Biodiversity in Ethiopia

Gole Tadesse Woldemariam[1] (twgole@gmail.com), Seyoum Aseffa[2]

[1] *Environment and Coffee Forest Forum, Addis Ababa, AA, Ethiopia* ; [2] *College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia*

Ethiopia possesses the most important and diversified genepool of *Coffea arabica* in wild populations, traditional landraces and cultivated varieties. The availability of high genetic diversity is fundamental for any crop improvement program for use by the plant breeders. This study presents economic valuation of *Coffea arabica* in terms of pest and disease resistance, increased productivity /yield, drought tolerance or climate change resilience, low caffeine content and higher cup quality.
The wild *Coffea arabica* embedded in the natural forest that has a wide range of benefits, including cultivated coffee genetic enhancement, provision of ecological services as well as an intrinsic value. This economic assessment estimated the values of *Coffea arabica* biodiversity in term of coffee genetic enhancement for increased yield, increased pest and disease resistance, low caffeine, high cup quality, drought and climate change resilience, and GHG reduction using indirect market-based of revealed preference techniques.
Our assessment revealed enormous potential of Ethiopia's Arabica coffee biodiversity to improve and sustainably produce coffee globally and in the country. If Ethiopia exploits its coffee genetic resources potential for coffee production in the country, it gets an additional benefit of USD 2.37-5.84 billion per year. Besides, if coffee producing countries use the genetic resources in Ethiopia to solve their coffee production problems, there is a potential economic benefit of USD7.6-8.1 billion per year. If users of these genetic resources are willing to pay 5% of their gain in economic benefit from the accessed Ethiopian coffee genetic resources to Ethiopia, the country can get additional income of about USD380-403 million per year.

Earthworm density regarding altitude, soil parental material, and soil chemical properties in coffee-based agroforestry in Beaumont and Pestel

Guervil Jephthé Samuel[1] (j.guervil@avsf.org), Jeune Wesly[2], Marichal Raphael[3], Jean-Denis Sardou[1]

[1] *AVSF, Delmas, Haiti* ; [2] *AVSF-Quisqueya University, Delmas, Haiti* ; [3] *CIRAD, Montpellier, France*

Rationale:
Beaumont and Pestel regions in South-West Haiti show high coffee cultivation potential. A study examined earthworm abundance as an indicator of coffee production, considering altitude, soil parent material, and chemical properties. Earthworms enhance soil porosity through litter decomposition, positively impacting coffee tree growth. There is a potential correlation between coffee bean weight and earthworm biomass. The study emphasizes the influence of environmental factors on earthworm abundance in Beaumont and Pestel.

Methods:
Earthworm sampling was conducted using the TSBF method, collecting specimens at litter and two depths in each monolith (0-10 cm and 10-20 cm). Significance analyses (ANOVA, Tukey's posthoc) and correlation tests explored the relationship between earthworms and soil chemical properties. Parent material identification relied on ArcGIS 10.4.1 software, utilizing Haiti's geological layers as the primary dataset.

Results:
Elevation positively correlated with earthworm abundance (r=0.61, P=0.00698), attributed to increased soil moisture at higher altitudes. Beaumont exhibited higher earthworm abundance, linked to significant altitude difference from Pestel. Negative correlations existed between earthworm abundance and soil pH (r=-0.52, P=0.02) and exchangeable calcium (r=-0.70, P=0.001). Negative correlations were also observed between Zn (r=-0.74, P=0.0004) and Mn (r=-0.73, P=0.0007) micronutrients with earthworm abundance. Coffee plots of different parent material types showed no significant difference in earthworm abundance. Pearson's chi-squared test (p=0.21) indicated dependency between parent material type and zone.

Conclusion & Perspectives:
Limited research on bioindicators, particularly earthworms, in Haiti, necessitates further investigation. Considering the significance of earthworms for soil quality, comprehensive studies are imperative. This study reveals variations in earthworm populations based on altitude and soil chemical properties in two coffee-growing regions.

Factors influencing the adoption of improved coffee varieties among smallholder farmers in Mbinga and Mbozi districts

Kiwelu Leonard (leonardkiwelu@gmail.com)

Special Projects and Business Unit, Tanzania Coffee Research Institute (TaCRI), Moshi, Kilimanjaro, Tanzania

Rationale:
Tanzania Coffee Research Institute (TaCRI) has released 19 Arabica coffee hybrid varieties that combine high yields with resistance to Coffee Leaf Rust (CLR) and Coffee Berry Disease (CBD). The high yield attribute of these improved varieties and reduced fungicide costs would normally motivate smallholder farmers to adopt them. However, their level of adoption by smallholders and the factors influencing it has not been studied in detail. This study aimed to assess smallholder farmers' perception of the varieties and determine factors influencing their adoption in Mbinga and Mbozi districts.

Methods:
Data were collected from a sample of 122 adopters and 198 non-adopters making a total of 320 farmers using a household survey semi-structured questionnaire. The perception of smallholder farmers on attributes of improved coffee varieties was gauged using a five-point Likert scale. A logistic regression model was employed to determine factors influencing their adoption.

Results:
The descriptive analysis showed that the rate of adoption of improved coffee variety is 38 % and the intensity of adoption is 42 %. The findings from the Likert scale showed that smallholder farmers in the study area have positive perceptions about the attributes of improved coffee varieties. Meanwhile, the findings from the logistic regression model showed that the coefficient of visits by extension officers (0.039), membership of primary cooperative (0.406), and access to improved coffee varieties (0.407) influence farmers' adoption decision of improved coffee varieties positively. However, access to market information (0.150), access to information about coffee varieties (0.149) and total land size owned (ha) (0.057) had a negative coefficient influence on the adoption of improved coffee varieties.

Conclusion & Perspectives:
Both adopters and non-adopters of improved coffee varieties have positive perceptions of the varieties. For more farmers to adopt these varieties, the lack of proper information about them and the lack of enough of their seedlings need to be addressed. Therefore, this study recommended that the coffee industry strengthen extension services to ensure the right information about these varieties is disseminated appropriately to farmers. Also, the government should provide support to coffee seedling multiplication and distribution to meet the demand.

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Application of Coordinated Regional Climate Downscaling Experiment (CORDEX-Africa) for projecting the future of coffee on the Mt. Kilimanjaro Ecosystem, Tanzania

Mbwambo Suzana[1] (suzana.mbwambo@tacri.org), Mourice Sixbert[2]

[1] *Productivity and quality improvement, Tanzania Coffee Research Institute, MOSHI, Tanzania* ; [2] *Sokoine University of Agriculture, Morogoro, Tanzania*

Rationale:
Climate change impacts are expected to be higher for coffee, a crop that is grown mostly by smallholder farmers. Adaptation is the only option to reduce the impacts. However, before we embark on determining adaptation strategies, it is important to conduct scientific research to understand possible pathways of future climate change which would guide for effective adaptation strategies. Therefore, this study aimed at producing climate change projections for the slopes of Mt. Kilimanjaro and determines its effect on future coffee production.

Methods:
The study was conducted on the slopes of Mt. Kilimanjaro with altitude range between 1000-1700 m.a.s.l. It utilized downscaled climatic data from CORDEX-Africa to project climate change in the near-term period (2026-2046). The Regional Climate Model (RCM) called RACMO22T, generated by a Global Circulation Model (GCM) known as ICHEC-EC-EARTH, was chosen for this work due to its low RMSE. The RCM datasets used in this study at daily scale consist of rainfall, minimum and maximum temperature for the RCM historical (1981–2001) and Representative Concentration Pathway (RCP) 4.5 projected (2026–2046) period. From the gridded RCM model data, a representative value was extracted and bias-corrected using the CMhyd tool. The projections were qualitatively interpreted on basis of the known climatic requirements for Arabica coffee.

Results:
Over 20-year baseline period, average rainfall on the slopes of Mt. Kilimanjaro w 500-3000 mm per annum. Projections indicated an increase in rainfall up to 13 %. During the baseline period the highest minimum temperature (Tmin) and maximum temperature (Tmax) were 19 °C and 29 °C respectively. Results revealed an increase in Tmin and Tmax during the Near-term period which varies between 1 - 2 °C and 1-1.2 °C respectively. Generally, high temperatures cause fruit abortions, reduced berry growth, and accelerate ripening, leading to reduction in coffee yield and quality. Moreover, Tmin increase the rate of respiration so the assimilates which could be used for growth and yield are reduced.

Conclusion & Perspectives:
It is clear that the impacts of climate change on future coffee yields will be considerably big in comparison with the baseline yields on the slopes of Mt. Kilimanjaro. These projected impacts are mainly attributed to increase in Tmin and Tmax and this call for urgent preparations of adaptation strategies such as planting shade trees and development drought tolerant varieties.

Coffee Frost Warning System in Southern Brazil

Morais Heverly[1] (heverlymorais@gmail.com), Costa Angela Beatriz Ferreira[2], Santoro Patricia Helena[1]

[1] *IDR-Parana, Londrina, Paraná, Brazil* ; [2] *Coffee Research Consortium/IDR-Parana, Londrina, Paraná, Brazil*

Rationale:
The climatic risk zoning of *Coffea arabica*in Brazil recommends cultivation up to 25º latitude, comprising part of the South of the country. Cultivation in higher latitudes is not recommended due to the high risk of severe frosts. The North and Northwest regions of Paraná are within the recommended zone, despite occurrences of light and moderate occasional frosts. To mitigate this problem, a Frost WarningSystem was started in 1995 by IDR-Paraná and SIMEPAR, whose purpose is to inform coffee growers in Paraná of the imminent occurrence of frosts, as well as recommend methods to protect their crops.
Methods:
The Frost Warning System operates annually from May to September, when there is risk of frost in Paraná. The polar masses moving towards Brazil are monitored and daily bulletins are issued with forecast information and possibility of frost capable of damaging crop plantations of Paraná. Warning may be published for the next 24, 48 or even 72 hours, depending on the intensity of the phenomenon. In addition to frost forecast, methods for protecting coffee crops are disclosed both for seedlings in the nurseries and plants with up to two years in the field. The daily frost warning bulletins are published in the IDR-Paraná and SIMEPAR websites, social media and the IDR Clima app.
Results:
The recommended methods for protecting coffee plants against frost, based on experimental tests during frost episodes are: 1. Nurseries: Cover the nurseries with double or triple plastic sheets. It is also recommended to distribute small heaters inside the nursery and to activate them during the night before the frost; 2. Newly planted seedlings: Cover seedlings up to 6 months old with soil or a thick layer of straw. The plants can remain covered for up to 20 days; 3. Extensive coffee plants: Soil banking close to the trunks up to the first pair of plagiotropic branches, for plants with 6 months to 2 years in the field. The soil must remain covering the coffee trunks during the entire period of risk of frost from May to September. In the 28 years of the Frost Warning System, 1 to 3 light or moderate frosts have occurred annually in the coffee region of Paraná. It was recommended, in all events, the immediate covering of the coffee plants, which protected efficiently the plantations and avoided severe prejudices to the farmers.
Conclusions & Perspectives:
During the operation of the Frost Warning System all frosts were predicted and there were no episodes false warnings. Coffee growers protected their newly formed nurseries and crops, avoiding losses. It is concluded that the Frost Warning System has been effective and important for coffee production in Paraná.

Strengthening climate resilience in coffee production in Chieng Chung commune, Mai Son district, Son La province

Nguyen Thao Ly (thaolyn97@gmail.com)

Climate Change and Development, Viet Nam Japan University (VJU), Ha Noi, Viet Nam

Rationale:
Intercropping coffee with other crops or forest trees has been proven to enhance and stabilize the agroecosystem and reduce the adverse effects of climate change. However, studies on the drawbacks and resilience level of intercropping compared to monocropping methods are limited, and research on the socio-economic aspects of this method is scarce.

Methods:
The research was carried out in Chieng Chung commune, Mai Son district, Son La province. A set of climate resilience indicators divided into five main dimensions, including social, economic, financial, environmental, and institutional, was developed. The climate resilience level of these households cultivating coffee in three agro-systems, namely, monocropping (18 farmers), intercropping with fruit trees (38 farmers), and intercropping with both fruit and forest trees (11 farmers), were assessed.

Results:
Monocropping farms have low climate resilience, while two intercropping methods show medium resilience. The productivity generated from growing coffee in intercropping with fruit and forest trees is 12.807 kg/ha, which is 5% more than growing with fruit trees, and almost 20% more than monocropping. Meanwhile, no income was generated from forest trees yet, and fruit trees usually have low revenue due to poor yields and low selling values. The investment costs of intercropping methods were around 58 million VND/ha while monocropping required lower investment costs, almost 47 million VND/ha. Farmers cited higher costs associated with intercropping due to increased fertilizer application and pesticide spraying. In addition, the training course on intercropping techniques is not as popular, particularly among those who practice monocropping, which accounts for only 29% of total monocropping farmers. Coffee monocropping and intercropping with fruit trees face moderate to severe challenges due to dry and acidic soil, pests, and diseases. In contrast, intercropped coffee trees with both fruit and forest trees face less difficulty. All coffee farmers are affected by frost, and drought is a considerable threat to 94% of monocropping coffee farmers, while intercropping methods are less susceptible, only 45% of farmers intercropping with fruit and forest trees and 58% of farmers intercropping with fruit trees are affected.

Conclusions & Perspectives:
Overall, understanding the limitations of intercropping coffee farming in Chieng Chung commune can help identify solutions to tackle social, economic, and environmental challenges, enabling farmers to build more resilient systems, taking advantage of the benefits of intercropping practices to promote sustainable livelihoods over the long term.

Climatic conditions profiling in coffee production areas; case of Kenya

Gimase James[1] (james.gimase@kalro.org), Odeny Danstan[2] (Danstan.Odeny@kalro.org)

[1] *Coffee Breeding, Kenya Agricultural and Livestock Research Organization, Nairobi, Kenya;* [2] *Coffee Agronomy, Kenya Agricultural and Livestock Research Organization, Nairobi, Kenya*

Rationale:
Coffee is a climate-sensitive crop. It is threatened by among others changes in temperature, amount, and distribution of rainfall. Substantial deviations, from standards norms, amount to climate change, expected to reduce land suitable for coffee by up to 50% Globally, mostly due to rising temperatures. The current study evaluated the extent of variation in rainfall and temperature within the coffee production regions in Kenya, to predict their influence on the suitability of the respective areas for coffee production.

Materials & Methods:
This study profiled changes in the amount and distribution of rainfall, and air temperature in six locations, Ruiru (Kiambu) Mariene (Meru), Kitale (Trans Nzoia), Namwela Bungoma), Koru (Kericho) and Kisii (Kisii) for 11 years and mean compared to long term changes spanning over 60 years. Mean changes per study condition were subjected to Principal Component Analysis (PC) using XLSTAT software.

Results & Discussion:
The analysis revealed optimum amount of rainfall, >1400mm in all locations, apart from Ruiru, with 1087.7 mm. There was a long-term increase in temperature of 0.9, 1.7, 1.1, and 0.3ºC in Ruiru, Mariene, Kisii, and Namwela, and a decline of 0.4 and 0.8ºC in Kitale and Koru respectively. The increased temperature is likely to reduce growth, flowering, and fruiting, and increase the pressure of pests. The PC 1 and 2 explained 77.2% of the total variations (Fig 1a) while the dendrogram separated the location into three main clusters: Kisii, Koru, Mariene in cluster 1, Ruiru cluster 2, Kitale and Namwela in 3 (Fig 1b).

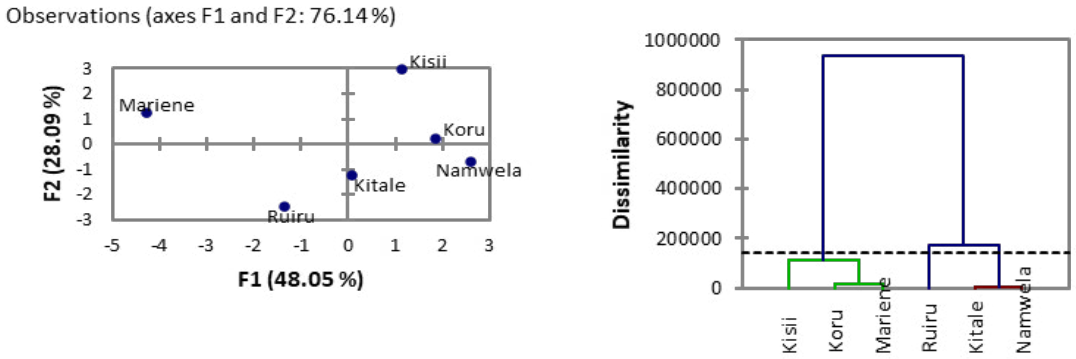

Fig 1: Multivariate analysis of the study conditions (a) Principal component analysis (b) hierarchical clustering.

Conclusions & Perspectives:
The analysis revealed substantial evidence of climate change in Mariene and Ruiru regions while the lowest variations in the study conditions were in Namwela and Kitale. Therefore, the current trend in the country on the promotion of coffee expansion in the region around these locations with low variations is strategic and sustainable.

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Use of Information Technologies among Coffee producing Households in the North Central, Nigeria

Oladokun Yetunde Olasimbo Mary (yetunde.oladokun@gmail.com), Oluyole Kayode Akanni

Economics and Extension, Cocoa Research Institute of Nigeria, Ibadan, Oyo, Nigeria

Rationale:
Information technology is an aspect of technologies needed by farmers to improve their production. In countries like Nigeria where most farmers are losing interest in coffee production because of no good market due to lack of appropriate processing techniques. Information technology is highly important for the farming households for improved production and market access. However there is a wide gap in the use of technology among coffee farmers in the study area. This study therefore seeks to examine the use of information technologies among coffee producing households in the North Central, Nigeria.
Methods:
Data from 120 coffee farming households were sourced using well structured questionnaire. Information on socio-economic characteristics, such as age, marital status, educational level, household size, socio-economic group membership, farming experience; information and communication technologies, such as phone calls, text messages, whatsapp messages, e-mail, facebook, radio, television, newspaper and effect of the use of information and communication technologies on productivity. Data were analysed using descriptive statistics (mean, percentages and charts).
Results:
Age and household size were 60.8±16.1 years and 7 ±5 persons, respectively. Most of the farmers were married (75.0%), while 54.2% had primary education, 83.3% belonged to socio economic association. The mean year of experience in farming was 28± 10years. Other crops grown with coffee were kolanut, plantain, maize and cassava. Information and communication technologies that were mostly used (high level of use) among the respondents were phone calls, the ones that were moderately used (medium level of use) were text messages, whatsapp messages, e mail, facebook and radio. The ones with low level of use were television and newspaper. Sixty seven percent of the entire farmers used information and communication technologies (ICT) for their farming activities. Forty two percent of the users of ICT used text messages and whatsapp messages to enhance coffee productivity. About fifty percent of the farmers agreed that information technologies affected their productivity at 10-50% and has improved their soil management skill and marketability of produce.
Conclusions & Perspectives:
The use of Information and communication technologies is prominent among coffee farming households in North Central, Nigeria and they affirmed the positive effect of the use of ICT on their productivity. Government and non-governmental organisations should educate farming households on the need to use information and communication technologies for their farming operations.

Sustainability Indicators of Vietnamese Coffe- and Pepper-led Farming Systems

Owusu Danquah Eric[1] (E.Owusu-Danquah@cgiar.org), Dinh Tram[2], Anders Sven[3], Notenbart An[4], Rahn Eric[5], Bienabe Estelle[6]

[1] *Research Scientist, agronomy & climate resilient cropping systems, Alliance Bioversity-CIAT, Vientiane, Laos, Vientiane, Ban Nong, Laos* ; [2] *Alliance Bioversity-CIAT, Hanoi, Vietnam, Hanoi, Hanoi, Vietnam* ; [3] *Resource Economics and Environmental Sociology, University of Alberta, Edmonton, Alberta, Canada* ; [4] *Africa Team Lead Tropical Forages Program, Alliance Bioversity-CIAT, Nairobi, Kenya, Nairobi, Nairobi, Kenya* ; [5] *Senior Researcher, Farming systems, Alliance Bioversity-CIAT, Hanoi, Vietnam, Hanoi, Hanoi, Vietnam* ; [6] *VScope Project Leader, World Agroforestry, Vietnam Office, Hanoi, Hanoi, Vietnam*

Rationale:
The expansion of coffee and pepper in Vietnam's Central Highlands (CH) has secured made the country the world's leading Robusta coffee and black pepper producer. However, this achievement has come at significant environmental costs (Dinh et al. 2022). Changing intensive farming practices is an urgent needs. Yet, existing guidelines on irrigation, nutrient management, intercropping, and agroforestry are insufficient and adoption rate remain low (Gaitán-Cremaschi et al. 2018). The V-SCOPE Project "Enhancing smallholder livelihoods in the Central Highlands of Viet Nam through improving the sustainability of coffee and black pepper farming systems and value chains" seeks to develop and implement suitable intervention models for coffee- and pepper-led farming systems that reduce unsustainable inout intensities while improving value-chain access and smallholder livelihoods.

Methods:
Within the VScope framework we conducted a farm-level survey in 2022-23 to assess the state of sustainabilty of different coffee- and pepper-led farming systems in the CH provinces of Dak Lak (Krong Nang district, n=412), Gia Lai (Dak Doa district, n=286) and Dak Nong (Dak Song district, n=362). The survey was built on the *RHOMIS* approach (Rhomis 2018), an establish farm household multi-indicator tool, used worldwide to assess sustainability in farming systems, practices, livelihoods, and food security. The survey provides a detailed account of intensity of fertilizer, pesticide, and irrigation practices that can be linked to important production, output, value-chain, and livelihood data for CH agriculture. We perform hierachical clustering analsyses to measure sustainability indictaor across mono- and intercropping farm typologies with agroforestry.

Results:
Here we share preliminry results of farm typologies by their environmental, economic, social sustainability status. A focus of the analysis is to identify diffrences in cheimcal input usage patterns and irrigation intensities that can infom the development of targeted interventions strategies for more sustainable soil management strategeis and related learning tools suitable for diverse farm households, agro-econological zones, and economic realities. Our preliminary results identify distinct cluster of larger, profitable and Kinh-owned (74%) farms (2.1 ha) with clear land rights already diversified beyond coffee or pepper, growing 3.87 cash crops on average. In contrast ethinc minority farms are smaller (1.53 ha) with unstable land rights (65%) and a more likely to be farming sloped. By groups show high and varying levels of fertiliser use and irrigation.

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What makes Vietnamese Coffee farmers adapt to climate change – Incremental versus system adaptation strategies?

Pham Hoang Giang[1] (G.Pham@cgiar.org), Nguyen Phuong Minh[2], Talsma Tiffany[2], Anders Sven[3], Nguyen Kien T.[2]

[1] *CIAT ASIA Regional Office, Hanoi, International Center for Tropical Agriculture (CIAT), Hanoi, Hanoi, Vietnam* ; [2] *CIAT ASIA Regional Office, Hanoi, International Center for Tropical Agriculture (CIAT), Hanoi, Hanoi, Vietnam* ; [3] *Resource Economics and Environmental Sociology, University of Alberta, Edmonton, Alberta, Canada*

Rationale:
More frequent adverse weather events attributed to climate change increasingly threaten Vietnam's Robusta coffee sector (Dinh et al. 2022). Implementing adaptation measures may lessen their vulnerabilities, but evidence on whether and how farmers actual adapt remains unclear. Using the climate adaptation framework by Verburg ret al. (2019) this study investigates coffee farmers willingness to adopt different climate change adaptation options that differ in the scale of application and related implementation steps.

Methods:
We use data from the baseline survey of the "Weather Forecasting for Coffee Sustainability (WEFOCOS) project. The survey consists of 400 coffee farming households representing 4 major Robusta growing districts in 2 Central Highland provinces. The survey instrument elicited several modules including (i) farmer climate and risk perceptions, stakeholder trust; (ii) farm typology and livelihood; (iii) farming information sources; (iv) coffee productivity, labor, and profitability.

Results:
Preliminary results of ordinal logistic analyses suggest that information sources including friends and neighbours, ethnicity, and technology attitudes affect famers' adaptation decision and practice choices. Listening to advice from friends and neighbours positively influences farmers' incremental (e.g., changing input use) and system (e.g., income diversification) adaptation choices compared to doing nothing. Meanwhile, ethnic minority farmers are found less likely to employ any adaptation options. Positive farmer attitudes towards technology are a predictor of systemic climate adaptation strategy adoption.

Conclusions & Perspectives:
While tangible climate adaptation measures are available for coffee farming systems, a poor understanding of farmer needs and barriers to adaptation are limiting on-farm implementation. Access to trusted information, barriers along ethnic divides, and learning about climate practices remain issues for many Vietnamese smallholder coffee farmers. Our findings are valuable for local authorities, extension practitioners, and donors active in the coffee sector, and those delivering information and training services towards more climate resilient coffee production.

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Discrimination of fermented Amazon robustas coffees by FTIR and PLS-DA

Bárbara Zani Agnoletti[1] (barbara.za@hotmail.com), Enrique Anastácio Alves[2], Rodrigo Barros Rocha[2], Lucas Louzada Pereira[3], Emanuele Catarina Da Silva Oliveira[3], Paulo Roberto Filgueiras[1]

[1] *Chemistry, Federal University of Espírito Santo (UFES), Vitória, Espírito Santo, Brazil* ; [2] *The Brazilian Agricultural Research Corporation (Embrapa), Porto Velho, Rondônia, Brazil* ; [3] *Federal Institute of Espírito Santo (IFES), Venda Nova do Imigrante, Espírito Santo, Brazil*

Rationale:
Fermentation has been applied as an emerging method to enhance the chemical and sensory characteristics of coffee. From the chemical point of view, this study evaluated Amazon robustas coffees (*Coffea canephora*) natural dry process and fermented dry process, to identify the chemical compounds related to the discrimination of these processes.

Methods:
A total of 47 samples of Amazon robusta coffee underwent the natural dry process. In another portion, 51 cherry samples were fermented for an average period of 15 days and subsequently dried (fermented dry process). The chemical analysis involved the examination of roasted coffee using Fourier transform mid-infrared spectroscopy (FTIR).[1] The acquired spectra were pre-processed using the first derivative with a polynomial of degree 2 and a 15-point window, followed by mean-centered. Partial least squares discriminant analysis (PLS-DA) was employed as the classification model to distinguish samples based on the processing method utilized.[2]

Results:
The PLS-DA model exhibited 100% accuracy for the training set and 90% accuracy for the test set. By utilizing the Variable Importance of Projection (VIP) score, which provides a significant measure of the predictive variables of the model, significant regions of the spectrum were identified with wavenumber values between 2940-2840 cm^{-1}. These regions were associated with symmetric and asymmetrical stretching bands C–H bonding of CH_2 and CH_3 groups, which are commonly related to the presence of lipids and caffeine.[3] Additionally, other relevant regions were observed, including bands between 1750-1700 cm^{-1} attributed to lipids and bands between 1650-1550 cm^{-1} attributed to caffeine.[3]

Conclusions & Perspectives:
The chemical markers responsible for discriminating between natural dry process and fermented dry process of Amazon robusta coffee were lipids and caffeine. Future studies should focus on evaluating the fermentation factor and its influence on the sensory quality of the beverage.

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Green and buoy coffee waste as an important source of antioxidant compounds for industry

Castro Isabel Samila Lima[1, 2] (samilalcastro@gmail.com), Caixeta Eveline Teixeira[1, 3], Rodrigues Laís Azevedo[2], Leite João Paulo Viana[2], Ribon Andrea de Oliveira Barros[2], Aguilar Ananda Pereira[2], Mendes Tiago Antônio de Oliveira[4]

[1] *Institute of Biotechnology Applied to Agriculture, Lab BioCafé, Universidade Federal de Viçosa – UFV, Viçosa, MG, Brazil* ; [2] *Department Biochemistry and Molecular Biology, Universidade Federal de Viçosa – UFV, Viçosa, MG, Brazil* ; [3] *Embrapa Café, Brazilian Agricultural Research Corporation–Embrapa, eveline.caixeta@embrapa.br, Brasília, DF, Brazil* ; [4] *Department Biochemistry and Molecular Biology, Universidade Federal de Viçosa – UFV, tiagoaomendes@ufv.br, Viçosa, MG, Brazil*

Rationale:
The coffee production chain generates waste that can cause significant social and environmental impacts. This work aimed to evaluate the presence of antioxidant phenolic compounds in extracts of green and buoy arabica coffee, considered waste for special and good quality coffee production. After harvesting the coffee, it goes through a washer, where separate the ripe fruits (good quality "cherries") and green and buoy, which have low quality beans for coffee beverage.

Methods:
The chemical profile of the different extracts and bioactive fractions were obtained using different solvents. We analyze the antioxidant and antimicrobial activity, cytotoxicity and stability of the hydroethanolic extracts.

Results:
Liquid chromatography analysis coupled with mass spectroscopy showed that the different extracts and fractions have similar chemical profiles, with the presence of chlorogenic acids, caffeine and sucrose. Thus, extraction with ethanol proved to be more appropriate for obtaining antioxidant compounds from fruits. The hydroethanolic extracts did not show antimicrobial activity. However, analysis of total phenolic content indicated potential antioxidant activity, which was confirmed by the DPPH. (2,2-diphenyl-1-picryl-hydrazyl) and ABTS+[2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid)] assays. The in vitro toxicity test with VERO cells (African green monkey kidney cell line) using MTT [3-(4,5- dimethylthiazol-2-y1)-2,5-diphenyl tetrazolium bromide] reagent, carried out in order to evaluate the safety and toxicity of the extracts, indicated that no evaluated concentration of extracts (50 – 1600 µg/ml) reduced cell viability by 50%, indicating that the extracts are not directly toxic to cells. In contrast, the results showed an increase in cell proliferation and/or mitochondrial activity in some evaluated concentrations. These data suggest the potential healing effect of the evaluated extracts, in addition to their antioxidant potential, since the induction of cell proliferation is an important mechanism in wound healing. Accelerated stability test showed that the antioxidant capacity of the bioactive compounds in the buoy and green coffee extract exposed at different temperatures (4 and 37 °C) remains high (above 50%) for at least 90 days in storage.

Conclusions & Perspectives:
Thus, the extracts have the potential to be used as a source of antioxidant compounds, and can be incorporated in the production of active and biodegradable packaging for food preservation, adding value to the coffee crop.

Keywords: Chlorogenic acids - Arabica coffee - Cytotoxicity - Bioactive extracts - ABTS - DPPH.

Funding: CNPq, FAPEMIG, CBP&D/Café and INCT-Café

Evaluation of the impact of co-inoculation of bacteria and yeasts on the quality of coffee (*Coffea canephora* var. Conilon) through NMR analysis

dos Santos Gomes Willian[1] (gwill.bio@gmail.com), Louzada Pereira Lucas[2], da Silva Oliveira Emanuele Catarina[2], Cardoso Golçalves Leonardo[2], Moreira Réboli Isabelli[2], Pereira de Araújo Sarah Cristina[2], Partelli Fábio Luiz[3]

[1] *Coffee Design Group, Universidade Federal do Espírito Santo, Alegre, ES, Brazil* ; [2] *Coffee Design Group, Instituto Federal do Espírito Santo, Venda Nova do Imigrante, Espírito Santo, Brazil* ; [3] *Department of Agrarian and Biological Sciences, Universidade Federal do Espírito Santo, São Mateus, Espírito Santo, Brazil*

Rationale:
Studies have been dedicated to the use of yeast and bacteria as starter cultures during fermentation, in order to modulate the chemical and sensory characteristics of coffee. However, this effect is still unknown for *C. canephora*. Thus, the objective of this study was to evaluate the chemical quality of the co-inoculation of yeast and bacteria during fermentation of *C. canephora*.
Methods:
Fruits of *C. canephora* var. Conilon were submitted to co-inoculation of *S. cerevisiae* and *L. brevis*, during 24, 48, 72 and 96 hours of fermentation. The Nuclear Magnetic Resonance spectra were obtained according to the methodology followed by Brioschi Junior et al., [1].
Results:
In this study, 10 compounds were identified (Figure 1). Although many of these compounds are directly related to coffee quality [2], the fermentation conditions employed were not able to suggest clear correlations between fermentation time and the formation of chemical compounds.
Conclusions & Perspectives:
Despite the potential of the method, it is necessary to better understand the biochemical mechanisms involved in the bacteria-yeast interaction, as well as its impact on sensory modulation in *C. canephora*.

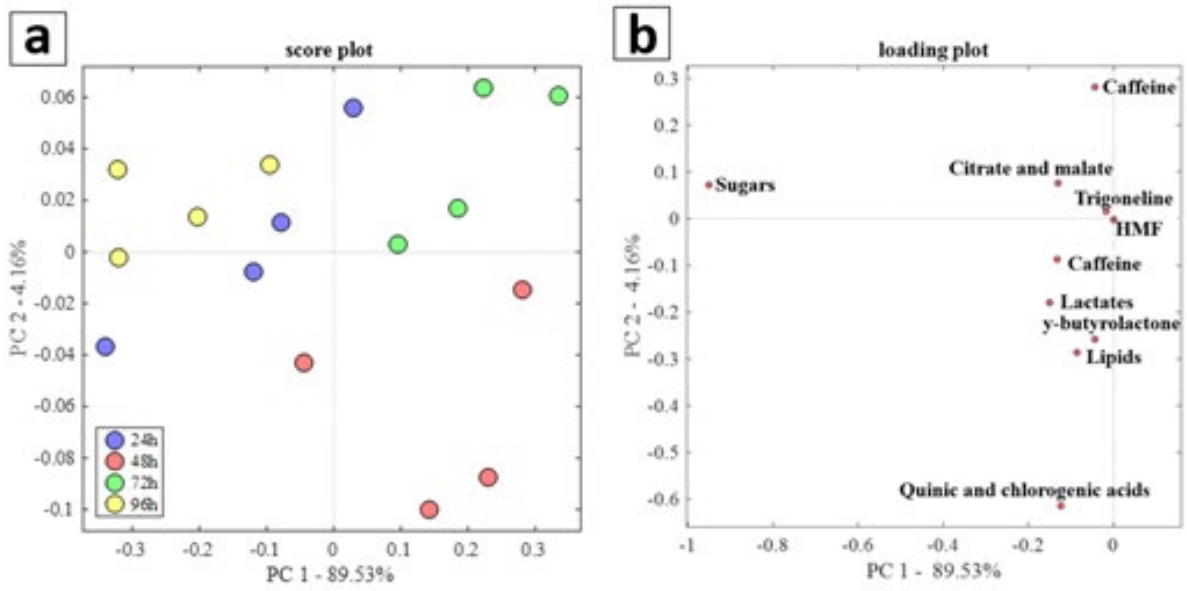

Figure 1 Evaluation of 24, 48, 72 and 96 hours of fermentation in the co-inoculation of S. cerevisiae and L. brevis using principal component analysis (PCA). (a) PCA Score plot. (b) PCA loading plot.

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Role of agro-forestry systems as design tools to control physico-chemical properties of green coffee beans

Fisk Ian[1, 2] (ian.fisk@nottingham.ac.uk), Xu Su[3], Liu Yuze[3], Ma Fengwei[3], Yang Ni[4], Sun Zhenchun[5], De Melo Verginio Filho Elias[6]

[1] *International Flavour Research Centre, University of Nottingham, Nottingham, Nottinghamshire, United Kingdom* ; [2] *International Flavour Research Centre (Adelaide), University of Adelaide, Adelaide, SA, Australia* ; [3] *Food and Pharmaceutical Engineering Institute, Guiyang University, Guiyang, Guiyang, China* ; [4] *International Flavour Research Centre, University, Nottingham, United Kingdom* ; [5] *International Flavour Research Centre, U, No, United Kingdom* ; [6] *Centro Agronómico Tropical de Investigación (CATIE), Turrialba, Costa Rica*

Twenty agro-forestry systems with different shade types and managements (organic and non-organic) consisting of an incomplete randomized block-design with shade tree as main effect and subplots represented by management were utilized as part of an experiment established in 2000 at CATIE (Tropical Agricultural Research and Higher Education Center), Turrialba, Costa Rica.
The effects of different managements and shade types on the physical and chemical attributes of green coffee beans was investigated. Different cultivation managements had a significant impact ($P<0.05$) on minerals, total lipid, fatty acids and caffeine content of coffee. Different shade type also had a significant effect ($P<0.05$) on the physical and chemical attributes of green coffee beans due to the variation of microclimate of the coffee plant under the different shade trees.
These insights may offer coffee growers and producers additional tools to optimize coffee bean chemistry.

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A study of BOD reduction from hemodialysis wastewater using spent coffee grounds

Iwabe Honoka[1] (2021bme007@s.morinomiya-u.ac.jp), Muraoka Minami[1], Araki Harutaka[1], Inoue Ryota[1], Naramura Tomotaka[1], Kudo Shintaro[2], Iwai Kazuya[3], Fukunaga Taiji[3], Tsuji Yoshihiro[1]

[1] *Department of Medical Engineering, Faculty of Medical Sciences Technology, Morinomiya University of Medical Sciences, Osaka-city, Japan* ; [2] *Inclusive Medical Science Research Institute, Morinomiya University of Medical Sciences, Osaka-city, Japan* ; [3] *Research & Development Department, UCC Ueshima Coffee Co., Ltd., Kobe-city, Japan*

Rationale:
Recycling coffee grounds are desirable to alleviate environmental problems. In this study, we report the purification of hemodialysis (HD) wastewater using carbonized coffee grounds. The dialysate contains organic substances such as acetic acid and glucose, which increase biochemical oxygen demand (BOD). Therefore, dialysis facilities need to be equipped with wastewater treatment equipment because the pH and BOD of dialysis wastewater are significantly different from those of general domestic wastewater. However, the installation of wastewater treatment equipment that reduces BOD is not widespread. BOD represents the amount of oxygen consumed by bacteria and other microorganisms during the decomposition organic matter under aerobic conditions. A higher BOD value indicates a higher amount of organic matter or pollution. Therefore, we attempted to find a way to purify dialysis wastewater using carbonized coffee grounds instead of a wastewater treatment system to reduce the BOD in HD wastewater.

Methods:
The coffee grounds were heated at approximately 600 °C for 1 h, held for 60 min, and cooled naturally to produce carbide in an electric furnace. Next, 1-25 g of carbonized coffee grounds was added to the dialysate wastewater with dilution water and stirred for 5 min, and the BOD value was measured. The diluted water was obtained from a river that was to be simulated for discharge into the river. The samples were shaken in a thermostatic dark room at 20°C, and the BOD values were measured for 5 days. The BOD was measured by a respirometer using the BOD system BD600, Lovibond).

Results:
Five-day analyses were carried out for the BOD determination of dialysis wastewater with different volumes of carbonized coffee grounds and dilution water. Results show a significant decrease of the BOD load for the dialysate wastewater added the carbonized coffee grounds in compare to dialysate wastewater non-added the carbonized coffee grounds.

Conclusions & Perspectives:
This study showed that carbonized coffee grounds can reduce BOD in dialysis wastewater.
This investigation suggests that carbonized coffee grounds adsorb glucose from the dialysis effluent, which is the main source of nutrients for the growth of aquatic bacteria. In reality, the amount of adsorption by carbonized coffee grounds is considered to vary depending on various phenomena such as water velocity, stagnation time, and initial concentration of organic matter in the water. Further research is required to realize the practical use of coffee grounds for dialysis wastewater treatment and water purification.

Green Extraction of Active Compounds from Coffee Cherry Husks with Alternative Deep Eutectic Solvent

Watla-iad Kanchana[1, 2, 3] (kanchana.wat@mfu.ac.th), Suwunwong Thitipone[1, 2], Choto Patcharanan[1, 2]

[1] *School of Science, Mae Fah Luang University, Chiang Rai, Thailand* ; [2] *Center of Chemical Innovation for Sustainability, Mae Fah Luang University, Chiang Rai, Thailand* ; [3] *Coffee Quality Research group, Mae Fah Luang University, Chiang Rai, Thailand*

Rationale:
Coffee production plays a crucial economic role in Chiang Rai, Thailand. This production brings a huge amount of waste including coffee cherry husks (CCHs) which is one of the main by-products. Nevertheless, it was previously reported that bioactive compounds are significantly present in CCHs [1]. For this reason, the extracts of active compounds from CCHs are interesting. Deep Eutectic Solvents (DESs) are an alternative solvent for green extraction of food and natural products due to their advantages such as non-toxicity and biodegradability. In this work, the optimal extraction of active compounds from CCHs using DES composed of choline chloride (ChCl) and citric acid monohydrate (CA) were studied.

Methods:
DESs was prepared by heating ChCl and CA with 1:2 molar ratio, at 80 °C until it becomes homogeneous. The ChCl was characterized by the FTIR spectrum. The physical properties of melting point and viscosity were measured using DSC and rheometer, respectively. The obtained homogeneous mixture was quite vicious. Thus, the amount of water additions varied from 20%-50%. The extraction process was assisted with the usage of ultrasound waves at room temperature (30 °C) for 60 min. The extraction efficiency was determined in terms of total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activity (AA) presented in the crude extracts.

Results:
It was found that the DES with 40% by weight water addition is the optimum condition for extraction. The levels of TPC, TFC, and AA measured from this condition were found to be 27.00 ± 1.18 mg gallic acid equivalents/g of DCCHs, 17.19 ± 0.12 mg catechin equivalent/g of DCCHs, and 11.24 ± 0.32 mg ascorbic acid equivalent/g of DCCHs.

Conclusions & Perspectives:
Green extraction methods using the prepared DES are practical for extraction of active compounds from CCHs and could be developed in the future for value-added products such as supplementary food and cosmetics.

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Chemical and bioactive composition of coffee by-products: from field to roasting

Machado Marlene[1] (marlenemachado753@gmail.com), Espírito Santo Liliana[1], Machado Susana[1], Lobo Joana C.[1], Costa Anabela S. G[1], Oliveira Maria B. P. P.[1], Ferreira Helena[2], Alves Rita C.[1]

[1] *REQUIMTE/LAQV, Dep. of Chemical Sciences, Fac. of Pharmacy, Univ. of Porto, Porto, Portugal* ; [2] *REQUIMTE/UCIBIO/i4H, Dep. of Biological Sciences, Fac. of Pharmacy, Univ. of Porto, Porto, Portugal*

Rationale:
Coffee companies produce considerable amounts of by-products. It is, therefore, crucial to find ways to valorize them, avoiding their disposal into the environment.[1] The aim of this work was to evaluate the chemical and bioactive composition of different by-products from coffee processing to roast, namely, pulp, husk, parchment, defective beans, green coffee sieving residue, and silverskin.
Methods:
The following parameters were determined: protein, lipids, dietary fiber, and ash contents, by AOAC methods [2]; chlorogenic acids profile, caffeine, and 5-HMF, by RP-HPLC-DAD; total phenolic and total flavonoid contents and antioxidant activity by spectrophotometry [3,4].
Results:
All the analysed coffee by-products are rich in total dietary fiber (up to 94.19% dw for parchment) and good sources of protein (up to 16.31% dw for silverskin). Sieving residue and defective beans can be highlighted for their high total phenolic content (5.11 and 6.54 g chlorogenic acid eq./100g dw, respectively) and high antioxidant activity (DPPH● inhibition: 2.85 and 3.11 g Trolox eq./100 g; Ferric reducing power: 17.56 and 17.68 g ferrous sulfate eq./100g dw, respectively). Overall, all the samples are sources of caffeine (0.06-0.85 g/100g dw, from parchment to defective beans) and chlorogenic acids, especially 5-caffeoylquinic acid (5.36-3787.58 mg/100 g dw, from parchment to defective beans). Silverskin exhibited a 5-HMF content of 39.5 mg/100 g dw resulting from the dehydration of sugars during roasting.
Conclusions & Perspectives:
In conclusion, coffee by-products, from field to roasting, are rich sources of bioactive compounds, especially chlorogenic acids and caffeine. However, the differences found in the chemical quantitative profile and nutritional composition can broaden their potential applications. Future studies should focus on the effects of coffee by-products on human health, development of functional foods, and ensuring food security.

Funding: This work was funded by the project PTDC/SAU-NUT/2165/2021- COBY4HEALTH- Can coffee by-products decrease the risk of metabolic syndrome? A comprehensive approach to reduce waste and valorize health benefits, funded by FCT/MCTES, Portugal.

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Effects of neutralization for acidic hemodialysis wastewater by using coffee grounds

Muraoka Minami[1] (2021bme063@s.morinomiya-u.ac.jp), Iwabe Honoka[1], Araki Harutaka[1], Inoue Ryota[1], Naramura Tomotaka[1], Kudo Shintaro[2], Iwai Kazuya[3], Fukunaga Taiji[3], Tsuji Yoshihiro[1]

[1] *Department of Medical Engineering, Faculty of Medical Sciences Technology, Morinomiya University of Medical Sciences, Osaka-city, Osaka, Japan* ; [2] *Inclusive Medical Science Research Institute, Morinomiya University of Medical Sciences, Osaka-city, Osaka, Japan* ; [3] *Research & Development Department, UCC Ueshima Coffee Co.,Ltd., Kobe-city, Hyogo, Japan*

Rationale:
Finding a new method for recycling coffee beans after extraction (coffee grounds) is important from the point of view of food recycling. Therefore, we attempted to neutralize acidic hemodialysis (HD) wastewater in the field of chronic HD using carbonized coffee grounds. Acidic cleaning solutions are usually used to remove calcium carbonate scales and biofilms from the piping of HD systems. When the acidic cleaning solution is discharged into sewage, neutralizing equipment is used to neutralize the wastewater. Neutralizing equipment adjusts and drains acidic or alkaline liquids to a neutral range. A sodium hydroxide solution (NaOH) was used to neutralize the acidic wastewater, and sulfuric acid or hydrochloric acid was used to neutralize the alkaline wastewater. In this study, we investigated whether carbonized coffee grounds could be used as an alternative to aqueous NaOH for the neutralization of acidic wastewater in the HD medical field.
Methods:
Coffee grounds were heated at about 600°C in 1 hour, held for 60 minutes, and cooled naturally to produce carbide in an electric furnace. The acidic HD wastewater sample was acidic wastewater (pH 1-3) from washing and sealing peracetic acid formulations (Cure-XL II; A.N TEC Co., Ltd., Shiga, Japan) commonly used in HD centers in Japan. Next, 1-25 g of carbonized coffee residue was immersed in 100-400 mL of acidic wastewater at different pH levels for 1 min, stirred, and the pH levels were measured.
Results:
Acidic HD wastewater was neutralized in each condition of this study by carbonized coffee grounds to a neutral pH range of 5.8 to 8.6, which is acceptable for discharge into public water bodies (Water Pollution Prevention Act; Japan).
Conclusions & Perspectives:
This study showed that carbonized coffee grounds neutralized acidic HD wastewater. To neutralize 100 L of approximately 1% acetic acid solution (pH 3) to pH 5.8-8.6, 100 times the volume of water or 10,000 L of diluted solution is required. The neutralizing effect of carbonized coffee grounds on acidic HD wastewater is expected to reduce the use of aqueous NaOH and water and improve the aquatic environment. Further research should be conducted to improve aquatic conservation.

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Evaluation of the volatile composition of cultivation of coffee in different agroforestry systems submitted to different post-harvest processing

Oliveira Emanuele Catarina da Silva[1] (emanuele.oliveira@ifes.edu.br), Simmer Marinalva Maria Bratz[2], Pereira Lucas Louzada[1]

[1] *Coffee Design Group, Federal Institute of Espírito Santo, campus Venda Nova do Imigrante, Venda Nova do Imigrante, Espírito Santo, Brazil* ; [2] *Department of Chemistry, Federal University of Espírito Santo, campus Goiabeiras, Vitória, Espírito Santo, Brazil*

Rationale:
The *Coffea arabica* species is characterized by adapting to different agricultural systems, however, the two commonly known are full sun agricultural systems and agroforestry systems (AFS). Agroforestry is the intentional integration of trees into crop farming systems.[1] This study aimed to evaluate the volatile composition of coffee cultivated in two agroforestry systems (AFS), the syntropic AFS and the natural/wild AFS.

Methods:
Arabica coffee fruits were harvested in Maciço do Baturité region, Ceará, Brazil, in two different AFS and 5 processes: Natural, Semi-dry, Washed, Yeast and Bacterial Fermentations. The Gas Chromatography coupled with mass spectrometry was applied for identification of volatile compounds present in the coffee samples.

Results:
Gas chromatography was able to identify chemical alterations in roasted coffee beans from different agroforestry systems. Additionally, distinct groups were observed within the same system based on the type of processing applied. In the case of coffee samples from the natural/wild AFS, a clear separation trend of the semi-dry and natural treatments was observed in relation to the others treatments. This separation was influenced by compounds such as alcohols and acids, in addition to esters and caffeine. In contrast, when examining the syntropic AFS, a noticeable separation was observed between treatments involving induced fermentation and the other treatments. The classes of aldehydes, sulphurous compounds, peroxides, alcohols, and acids were predominantly found in the Washed, semi-dry, and Natural treatments, indicating that these variables were responsible for the differentiation between the treatments.

Conclusions & Perspectives:
The chromatographic analysis enabled the identification of changes in the profile of volatile compounds in coffee cultivated under various agroforestry systems. Additionally, it allowed for differentiation between post-harvest treatments. AFSs and fermentation processes significantly impact the chemical quality of coffee beans.[2]

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Straw -to-grain ratio of fruits of 20 *Coffea canephora* genotypes

Partelli Fábio[1] (partelli@yahoo.com.br), Rodrigues Maria[2], Silva Cleidson[3], Silva Larícia[2], Vieira Henrique[4], Ramalho José[5]

[1] *DCAB, Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [2] *Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [3] *Federal University of Lavras, Lavras, MG, Brazil* ; [4] *State University of North Fluminense Darcy Ribeiro, Campos dos Goytacazes, RJ, Brazil* ; [5] *Lisbon University, Lisbon, Portugal*

Rationale:
Economically, the species *Coffea canephora,* with high genetic variability is the second most relevant in the world. Characteristics such as fruit size, grain size and productivity vary according to the genotype [1]. With a view to selecting plants with higher productivity and yield, the objective of this research was to measure fruit traits of 20 *C. canephora* genotypes.
Methods:
The experiment was carried out on a commercial plantation of 4-year-old trees of 20 genotypes (3.0 x 1.20 m spacing). Each genotype was harvested by hand when the fruits reached the mature (cherry) stage. They were dried to constant weight in a forced air oven at 50 °C. The fruits were processed by hand and the parts weighed separately. The project was funded by CNPq, CAPES, FAPES and UFES.
Results:
The genotypes 7, 8, 16 and 17 had the highest grain yield in relation to straw. Therefore, these genotypes can be exploited in breeding programs to achieve higher *C. canephora* yields. Genotype 13 had the lowest straw-to-grain ratio.
Conclusions & Perspectives:
Some genotypes had promising grain yield traits and can be considered highly productive; grain per fruit percentage is correlated with productivity.

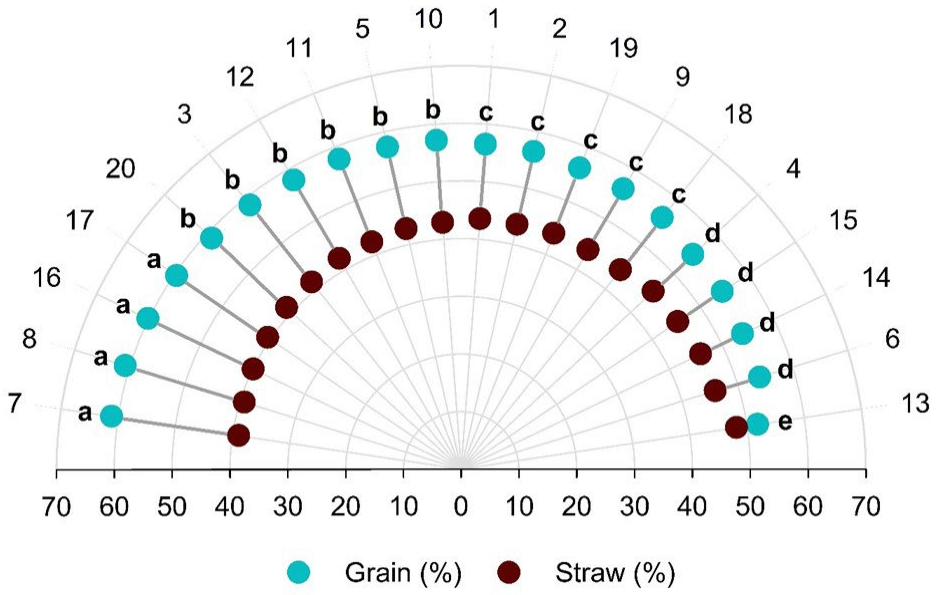

Figure 1. Grain percentage and straw in the fruits of 20 C. canephora genotypes. Vila Valério, ES–Brazil.

References:
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Nutrient acumulation in bean of diferent *Coffea arabica* cultivars in the mountains of Gorongosa National Park – Moçambique

Alberto Niquisse[1] (partelli@yahoo.com.br), Partelli Fábio[1], Ramalho José[2], Barros Ana[2], Viana Alexandre[3], Krohling Cesar[4], Moiane Sional[5], Alberto Zito[5], Rodrigues Weverton[6], Rakocevic Miroslava[7]

[1] *DCAB, Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [2] *Lisbon University, Lisbon, Portugal* ; [3] *State University of North Fluminense Darcy Ribeiro, Campos dos Goytacazes, Brazil* ; [4] *Incaper, Linhares, Brazil* ; [5] *Gorongosa National Park, Goinha, Mozambique* ; [6] *State University of the region Tocantina Maranhão, Imperatriz, Brazil* ; [7] *Federal University of Espírito Santo, São Mateus, Brazil*

Rationale:
Coffee is socially and economically very important, representing an important source of revenue and employment in several tropical countries [1]. This study was to evaluate macronutrient accumulation in bean of *Coffea arabica* cultivars in the Mountains of Gorongosa National Park (PNG) – Mozambique.

Methods:
The N content was determined after sulfuric acid digestion using the Nessler colorimetric method; P by molecular absorption spectrophotometry; K by flame photometry; S by sulfate turbidimetry. The contents of Ca, Mg were determined by atomic absorption spectrophotometry [2]. The data were subjected to ANOVA ($p \leq 0.05$) by the F test, were compared by Tukey's test.

Results:
N, P and Ca did not differ among the cultivars. For K and Mg, cv. The mean S concentration was highest for cv. Costa Rica and lowest for cv. Catuaí Vermelho IAC 44. The mean concentrations of all macronutrients were highest for cv. Catucaí Vermelho 19/8.

Conclusions & Perspectives:
The evaluated cultivars showed higher accumulation of macronutrints N, K and Ca in coffee bean of *C. arabica.*
This study may underlie the development of future coffee cultivars for recommendation in Mozambique.

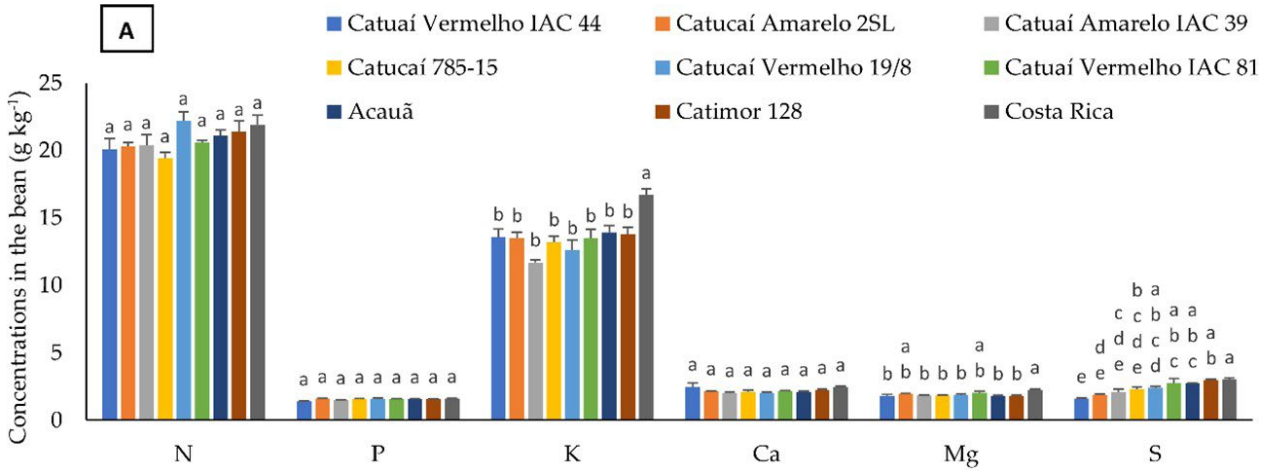

Figure 1. Macronutrients in the bean of nine Coffea arabica cultivars. The mean value ± SE (n=4) followed by different letters express significant differences between cultivars (a, b, c, d, e).

References:

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Nutrient accumulation in fruits of 20 *Coffea canephora* genotypes

Rodrigues Maria[1] (mariajuliete.rodrigues@hotmail.com), Salvador Henzo[1], Partelli Fábio[1], Silva Cleidson[2], Silva Larícia[1]

[1] *Federal University of Espírito Santo, São Mateus, ES, Brazil* ; [2] *Federal University of Lavras, Lavras, MG, Brazil*

Rationale:
In general, plants of the *Coffea canephora* species can store large nutrient amounts in the vegetative and reproductive tissues, which may be related to the fruit maturation cycle, plants age and crop management [1]. The objective of this study was to evaluate the cumulative nutrient amounts extracted in harvested fruits of *C. canephora* 20 genotypes.

Methods:
The experiment was carried out on a commercial plantation, in Vila Valério, Espírito Santo, Brazil. The crop consisted of 4-year-old trees of 20 genotypes (3.0 x 1.20 m spacing). The experimental design was randomized blocks, with four replications and five plants per plot. When the fruits reached the mature (cherry) stage, each genotype was harvested by hand. The fruits were dried to constant weight in a forced air oven at 50 °C and then depulped (husk separated from grain) by hand.
The concentrations of: nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, manganese, copper, zinc and boron in grain and husk were chemically analyzed. Nutrient accumulation in the fruits, was computed as the nutrient accumulation in grain (kg) + nutrient accumulation in husk (kg). The data were subjected to analysis of variance by the F test ($p<0.01$) and the means grouped by the Scott-Knott clustering method ($p<0.05$) for mean grouping. This research project was supported by CNPq, CAPES, FAPES and UFES.

Results:
Genotype 13 was noted for appearing most often in the groups with highest means, since it was classified in the best group for seven nutrients (N, P, K, Mg, Cu, Zn, B). With regard to the maturation cycle, the early genotypes (11, 14,16, 18) accumulated less nutrients than the medium- (1, 5, 7, 8, 9, 10, 15, 20) and late-cycle (2, 3, 4, 6, 12, 13, 17, 19) genotypes.

Conclusions and Perspectives:
Some genotypes accumulate more and some less nutrients than others. In addition, nutrient accumulation is correlated with the maturation cycle (early, medium and late). These results can significantly contribute to better-founded decisions for fertilization recommendations, as they help to complete the diagnosis of the nutrient amounts extracted at harvest.

References:

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Effect of Variety, Leaf Type & Processing Conditions on Sensory & Antioxidant content of Coffee Leaf Black Tea

Subramanian Siva[1] (siva.subramanian@ofi.com), Van Asten Piet[2], Patne Sanjay[3], Fong Leonard[4]

[1] *Coffee, Olam Food Ingredients, Willowbrook, IL, USA* ; [2] *Coffee, Olam, Singapore, Singapore* ; [3] *Coffee, Olam Food Ingredients, Paksong, Laos* ; [4] *Coffee Innovation, Olam Food Ingredients, Willowbrook, Illinois, USA*

Coffee leaf has been traditionally used as an ethnomedicine to ameliorate various diseases or acute disorders by local groups that live and thrive on plantations that produce principally coffee beans in growing countries. In the last 10 years, coffee leaf tea has come into prominence as a potential beverage due to the phytochemical composition. Black tea was processed through CTC method using coffee leaves obtained from different varieties and leaf type including Juvenile, Young and Mature leafs in pilot plant settings. The tea was evaluated for various quality parameters and characterized for various phytochemicals. 3 CQA was common across all coffee leaf tea samples and with the highest concentration. The black tea CTC process was able to produce a coffee leaf black tea which is comparable in quality to standard black tea in color, aroma, flavor and percent extractives. The extracts were evaluated for antioxidant capacities using ORAC and ABTS assays and intercellular antioxidant capacities using DCFH-DC and NO methods using Caco-2 cells. Results indicate that good corelation with the phenolic content of the coffee leaf tea samples. The antioxidant capacities are highest with younger leaves.

References:

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The Exploration of Coffee Roasting Profiles with Estimation of Chlorogenic Acid and Caffeine in Roasted Coffee Beans

Chung Hsiao-Yen (choco.seanchong@gmail.com), Liu Hsiuming

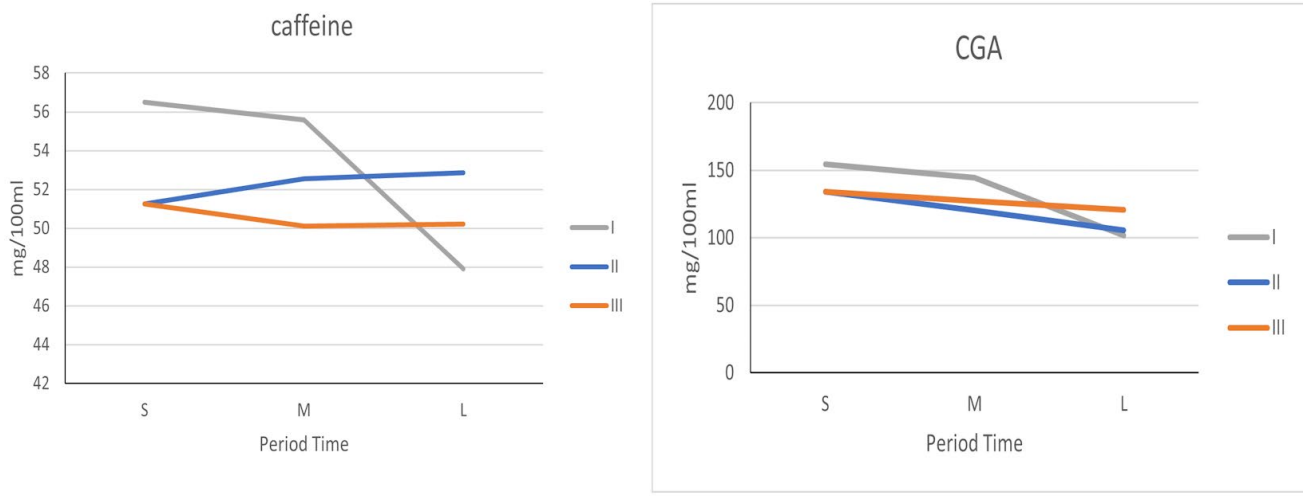
Department of Food Science, National Taiwan Ocean University, Keelung City, Taiwan

Rationale:
The flavor of chlorogenic acid (CGA) is sour and slightly bitter, and obviously astringent. Caffeine tastes bitter. These two chemical compositions have a great influence on coffee's flavor.[1-2] We tried to explore their variations in different roasting curves, then explored the influence of these variations on flavors.

Methods:
The new caffeine and CGA detector, GTC300, was used to examine the mounts of caffeine and CGA, instead of traditional HPLC.
The roasting curve could be divided into three periods, dehydration (period I), Maillard reaction (period II) and development (period III).[3]

Results:
Caffeine decreased more when longer the time of period I and III. That means caffeine exited more when we used fast roast. However, there was something special about period II. Longer the period time, more the amount of caffeine. That means if we would like to decrease bitter, we could shorten the time of period II.
As for CGA, whatever period I, II and III, longer the period time, the trends of decreasing were obvious.

Conclusions and Respectives:
The results could suggest roasting curves. More explorations of compositions by HPLC and GC should offer further discussions.



Roasting Periods

References:
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Optimal Control of Coffee Roasting Processes with Model Predictive Control

Pierl Dennis[1] (dpierl@iat.uni-bremen.de), Ampts Leif[1], Tück Sebastian[2], Koziorowski Thomas[2], Michels Kai[1]

[1] *Institute of Automation Technology, University of Bremen, Bremen, Germany* ; [2] *PROBAT AG, Emmerich am Rhein, Germany*

Rationale:
The roasting of coffee beans under high requirements and with consistent quality is a challenging task from a control engineering perspective. This results from two different factors: The various actuators of coffee roasters, which need to be coordinated with each other and the highly non-linear thermal behaviour of the coffee beans [1]. The here proposed approach addresses this by application of Model Predictive Control (MPC) using a Digital Twin (DT) of both coffee roaster and beans [2].

Methods:
This research focuses on the development of the DT of coffee roasters and the application of MPC to generate optimal control sequences for the roasting process. The DT of the coffee roaster intendeds to precisely describe the thermal processes within the roasting chamber. This involves modelling the characteristics and effects of all control elements such as the burner for heating the supply air, fans to generate the air flow through the roasting chamber and available valves/flaps. Furthermore, the time behaviour of measurement devices (e.g. thermocouples) is also considered. The parameterisation of the DT is individually carried out for each roaster by means of parameter identification, making it portable. Subsequently, the MPC algorithm uses the parameterised DT of the roaster to generate optimal control sequences for the roasting process. This approach intends to precisely trace predefined roasting curves and thus guarantees a consistent roasting result.

Results:
The first application of a prototype using this method in a coffee roaster already shows promising results. In a series of experiments, the roaster's DT is parameterised based on predefined control sequences and the resulting measurement data. To elucidate the improved control behaviour, this parameterised DT is used in MPC to e.g., control the supply air temperature entering the roasting chamber. For instance, manually introduced disturbances to the supply fan speed of up to 30 %, the maximum temperature deviation was 2 % or less from its setpoint (control error) as oppose to ~5 %, conventionally.

Conclusions & Perspectives:
This new control approach of using a DT in combination with MPC for coffee roasters presumably allows better reproducibility of roasting results. The tested prototype already shows better control behaviour than the commonly used set of controllers. However, both the DT and the MPC still show potential for further improvement. For example, the combination with a DT of the coffee beans is still pending and may lead to significant improvement. Nevertheless, the method has great potential for substantial energy savings due to enforcing optimal heat transfer to the beans.

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1. Di Palma, F.; Iacono, F.; Toffanin, C.; Ziccardi, A.; Magni, L.: "Scalable model for industrial coffee roasting chamber". Procedia Computer Science 180 (2021), ScienceDirect, Pp: 122-131.
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Impact on Sensory Quality and Physicochemical Changes in Coffee during Re-roasting

Suzuki Taroh (saza.suzuki.taroh@gmail.com), Amini Rasool Khan, Kitamura Yutaka[1, 1]

Life and environmental science, University of Tsukuba, Tsukuba, Ibaraki-ken, Japan

The impact of re-roasting and the physical changes occurring during the roasting process were investigated in this study. Coffee samples were roasted using a laboratory-scale roaster, and samples were collected every minute throughout the roasting process for subsequent physiochemical analysis. Additionally, the roasted coffee underwent a re-roasting process using same roasting profile.
The structural changes of the coffee during roasting were examined using scanning electron microscopy. Furthermore, the roasted coffee samples were subjected to analysis using GCMS and HPLC. Sensory analysis was conducted according to the SCA protocol for coffee sensory evaluation.
The results indicated that coffee roasted for 7 minutes with 5% moisture content during re-roasting exhibited superior sensory attributes. Further research will be conducted to analyze the aromatic and non-aromatic compounds in the re-roasted coffee.

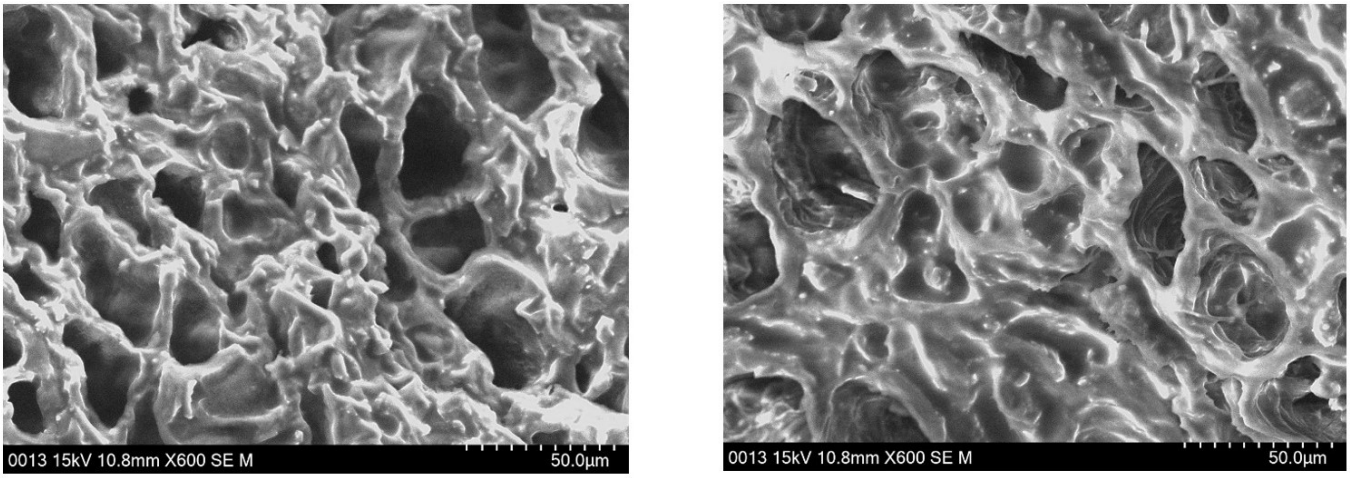

Fig 1. SEM observations of coffee beans (a) four minutes roasting (b) 12 minutes roasting.

Food Authenticity — HPLC determination of 16-O-methylcafestol of instant coffees

Dr. Speer Karl (speerrkarl@gmail.com), Dr. Kölling-Speer Isabelle, Dr. Buchmann-Hempel Sandra

Food Chemistry, TU Dresden, Dresden, Germany

Introduction:
The coffee species with the greatest commercial importance are *Coffea arabica* and *Coffea canephora var. robusta*. Within these species, Arabica coffees have a significantly higher market value than Robusta coffees. The botanical origin of coffee can be determined unambiguously by analyzing the concentration of the diterpene 16-O-methylcafestol (16-OMC) (1,2,3). Whereas Arabica coffee contents not detectable contents or only very small amounts of 16-OMC (less than 20 mg/kg), the concentrations in Robusta coffees are significantly higher in the approximate range of 800 to 2.500 mg/kg. Actually, the determination of 16-OMC in green and roasted coffees is described in the DIN method 10779. For instant coffees, there is no official method. Due to the specific extraction with water, instant coffee contains only very small quantities of 16-OMC, which are not be determinable with NMR analysis. Therefore, an HPLC method for analyzing 16-OMC should be developed.

Methods:
After direct saponification of the instant coffee powder the unsaponifiable fraction was isolated by liquid-liquid-extraction. In order to reduce impurities of the matrix an additional clean-up step via a solid phase extraction (SPE) using a silica gel cartridge had to be introduced.

Results:
The developed method allows for a clear evaluation of the HPLC chromatograms. Substances interfering with the analytes are removed by the developed clean-up step. For validation an Arabica instant coffee extract was spiked with 16OMC (appropriately 1.25 mg/kg; 2.5 mg/kg; 5.0 mg/kg; 10.0 mg/kg, 20.0 mg/kg instant coffee) prior to the SPE. Recoveries of 16OMC were in the range between 90% and 98%.

Conclusions & Perspectives:
The validated method enables a limit of quantitation (LOQ) of 2.5 mg/kg and a limit of detection (LOD) of 1.25 mg/kg. Therefore an addition of Robusta can be detected in an Arabica coffee declared as 100%. However, statements in regard to mixing ratios are not possible because the low 16-OMC contents detected very strongly depend on the extraction conditions used.

References:

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3. Speer, K. and Kölling-Speer, I.: In: Farah A, ed. Lipids in Coffee: Production, quality and chemistry. Croydon (UK), EPUB ISBN: 978-1-78801-658-2, The Royal Society of Chemistry; chapter 20: 2019:458-504.

Food Authenticity — Determination of 16-O-methylcafestol content of green and roasted coffee — HPLC-method; Method Validation Study of CEN/TC-460 WG 3

Dr. Speer Karl[1] (speerrkarl@gmail.com), Uhlig Steffen[2], Simon Kirsten[2], Frost Kirstin[2], Schlierf Anja[2]

[1] *Food Chemistry, TU Dresden, Dresden, Germany* ; [2] *QuoData GmbH, Quality & Statistics, Dresden, Germany*

Introduction:
The coffee species with the greatest commercial importance are *Coffea arabica* and *Coffea canephora var. robusta*. Within these species, Arabica coffees have a significantly higher market value than Robusta coffees. In unblended coffee the botanical origin of coffee can be determined unambiguously by analyzing the concentration of 16-O-methylcafestol (16-OMC) (1). Whereas Arabica coffee contents not detectable or only very small amounts of 16-OMC (less than 20 mg/kg), the concentrations in Robusta coffees are significantly higher in the approximate range of 800 to 2.500 mg/kg (2, 3).

Methods:
On behalf of the Federal Office of Consumer Protection and Food Safety (BVL), CEN/TC-460 WG 3 (Coffee and coffee products), an interlaboratory study for method validation was conducted for the determination of 16-OMC in coffee by means of HPLC. The aim was to revise the existing DIN 10779 because the proven method is time-consuming (approx. three days) and also requires a higher consumption of solvents.

Results:
A total of 16 laboratories participated in the validation study of the new method. The statistical analyses were performed in accordance with ASU § 64 LFGB on the basis of statistical approaches according to DIN ISO 5725-3 for a staggered-nested interlaboratory test design. Using this design, it was possible to determine not only the precision of reproducibility and repeatability, but also an intermediate precision within laboratories.

Conclusions & Perspectives:
From a statistical point of view, the new HPLC method can be considered successfully validated with the given precision parameters for the determination of 16-OMC in the working range from 40 to 1500 mg/kg. Nevertheless, some laboratories can also successfully analyze levels between 20 and 40 mg/kg. The method can be used equally for analyzing the 16-OMC content of green and roasted coffees.

References:

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Coffee Cuality 2.0 – New cupping, drip brew, cold brew and espresso evaluation designs, protocols and analyses

Guinard Jean-Xavier[1] (jxguinard@ucdavis.edu), Elliott Benjamin[2], Lim Lik Xian[1]

[1] *UC Davis Coffee Center, University of California, Davis, California, USA* ; [2] *Department of Food Science and Technology, University of California, Davis, California, USA*

The *Coffee Cuality* Method (www.coffeecuality.com) provides a comprehensive assessment of the sensory quality of coffee that includes an overall quality rating, just-about-right (JAR) scaling of select attributes, check-all-that-apply (CATA) selections from a list of sensory and holistic attributes and open comments.

We validated the method with 56 expert coffee tasters by comparing *Coffee Cuality* with their customary method (i.e., Q-grading, SCA's, company's own) for the evaluation of the sensory quality of 12 specialty coffees and commercial blends brewed with their preferred method (cupping, drip, pour over or espresso). A subset of 18 experts then participated in focus groups on *Coffee Cuality*.

Quality Mapping (principal component and cluster analyses of the quality ratings) showed consistency among the experts' overall quality ratings regardless of method, with the dark roasts rated systematically lower than the light- and medium-roasted coffees. Penalty analysis relating JAR ratings to quality scores showed that too dark of a roast or a beverage color and too low of an acidity had the largest (negative) impact on quality. The map of sensory and holistic attributes derived from CATA selections by correspondence analysis, and the word clouds of those selections showed which attributes drove quality ratings, positively or negatively. The focus groups provided valuable insights on the types and numbers of coffees that could be evaluated with the method and suggested improvements to the evaluation protocol and scorecard.

Based on the results of the expert evaluations and the key learnings from the focus groups, we are proposing new and improved (*Coffee Cuality 2.0*) experimental designs, evaluation protocols, and statistical analyses for cupping, drip brew, cold brew and espresso, as well as a framework for the evaluation of other coffee beverages.

References:

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Biovolatile fingerprinting of honey/pulped natural coffee with *Saccharomyces cerevisiae* fermentation

K N Aswathi[1, 2] (aswathimanoharan24@gmail.com), S Murthy Pushpa[1, 2]

[1] *Department of Plantation Products, Spices and Flavor Technology, CSIR-Central Food Technological Research Institute, Mysuru, Karnataka, India* ; [2] *Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, India*

Post-harvesting and microbial activity of coffee play a critical role in the metabolites and the sensory quality of the brew. The work focuses on the fermentation of pulped/honey Robusta coffee with a starter culture (*Saccharomyces cerevisiae* MTCC 173) and the identification of fermentation patterns through ^{1}H NMR, microbial ecology, volatomics and organoleptics of brew. Fermentation was accelerated by yeast populace (10 cfu log/ml) for 192 hours. The chemical characteristics such as carbohydrates (41.88 ± 0.77 mg/g), polyphenols (34.16 ± 0.79 mg/g), proteins (58.54 ± 0.66 mg/g), caffeine (26.54 ± 0.06 mg/g), and CGA (21.83 ± 0.04 mg/g) were also evaluated. The heatmap-based visualization of GC-MS accorded characterization of additional 5 compounds in treated coffee contributing to sweet, fruity and caramelly odor notes compared to untreated. The E-nose and E-tongue will be elaborated. scores. Preparation of Honey coffee with *Saccharomyces cerevisiae* is the first report, which modulated the flavor and quality of coffee.

References:

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Cup quality profiles of kenyan coffee processed by innovative methods

Kathurima Cecilia[1] (cecilia.kathurima@kalro.org), Gichuru Elijah[2], Kinoti Simon[3], Murimi Judith[4]

[1] *Chemistry, Kalro, Ruiru, Kiambu, Kenya* ; [2] *Pathology, KALRO, Ruiru, Kiambu, Kenya* ; [3] *FARM, KALRO, Ruiru, Kiambu, Kenya* ; [4] *Coffee Quality Control, Ibero (K) Ltd., Ruiru, Kiambu, Kenya*

Rationale:
Kenya coffee which is mainly fully washed is known for its quality and appreciated in the world market. With the changing consumer trends, it is worth exploring the potential of coffee through processing. The objective of this study was to process Kenyan coffee using alternative innovative methods and evaluate their impact on beverage quality.

Methods:
The test coffee variety was mature SL 28 planted in a commercial plot at KALRO-Coffee Research Institute (CRI). Ripe coffee cherries were harvested during the peak period in December 2022. The cherries were manually sorted after harvesting and subjected to floatation to remove floaters. The cherry was divided into two batches. One batch of fresh cherry was further subdivided to smaller batches which were processed as naturals, honey and fully washed. The second batch of cherry was subjected to anaerobic fermentation for 48 hours and then sub-samples processed as naturals, honey and fully washed. The dried coffee samples (natural, honey and fully washed) were hulled and graded as a prerequisite to roasting. Sensory evaluation procedure described by Lingle (2001) was followed in assessing the sensory quality of the samples.

Results:
The coffee samples processed by the different methods showed significant differences at ($P<0.05$) for the sensory variables evaluated. The impact of the innovative processing was apparent in the flavor, aftertaste, acidity, body, balance, and overall score attributes. All the coffees attained specialty grade (80 points and above) with naturals from 48 hour anaerobically fermented cherry attaining the highest total sensory score (87.5).

Conclusions & Perspectives:
This study shows that innovative coffee processing techniques can be rewarding in attaining excellent cup profiles. Anaerobic fermentation was unveiled as an area of unexploited potential in enhancing sensory quality of coffee.

References:

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The combined effects of shade and altitude on the quality of coffee beans grown at Gorongosa Mountain, Mozambique

Leitão António[1] (antonioleitao@isa.ulisboa.pt), Cassamo Crimildo[2], Pais Isabel[3], Moreira Rita[3], Chiulele Rogério[4], Haarhoff Quentin[5], Moiane Sional[5], Marques Isabel[6], Rodrigues Ana[6], Partelli Fábio[7], Ribeiro-Barros Ana[8], Ramalho José[8]

[1] *Centro de Estudos Florestais, GeoBioTec, Universidade de Lisboa, Instituto Superior de Agronomia, Oeiras, Lisboa, Portugal* ; [2] *Faculdade Engenharia e Tecnologias, Universidade Pedagógica de Maputo, Maputo, Mozambique* ; [3] *Instituto Nacional de Investigação Agrária e Veterinária, Oeiras, Portugal* ; [4] *Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane, Maputo, Mozambique* ; [5] *Gorongosa National Park, Goinha, Mozambique* ; [6] *Centro de Estudos Florestais, Universidade de Lisboa, Instituto Superior de Agronomia, Lisboa, Portugal* ; [7] *Departamento Ciências Agrárias e Biológicas, Centro Universitário do. Norte do Espírito Santo, Universidade Federal Espírito, São Mateus, Brazil* ; [8] *Centro de Estudos Florestais, GeoBioTec, Universidade de Lisboa, Instituto Superior de Agronomia, Lisboa, Portugal*

Rationale:
Environmental conditions related with shade and altitude are pointed to have beneficial effects on coffee bean quality, but there is some controversy about this subject. So, the purpose of this work was to study the effect of shade and altitude on the quality of coffee, grown in an agroforestry system at Gorongosa Mountain, Mozambique.

Methods:
Plants of *C. arabica* cv. Costa Rica 95 with 4 years old, cropped under two degrees of shade using native trees (deep shade, DS and moderate shade, MS) and full Sun (FS), at three altitudes (650, 825 and 935 m), were studied as regards the impact of light conditions and altitude on bean quality. Physical and chemical analyses for quality evaluation were carried out on green beans and included: colour parameters, phenolic acids (CQAs, diCQAs, FQAs, *p*-coumaric acid), and caffeine and trigonelline [1].

Results:
Colour attributes showed some changes among altitudes, but never modified by light conditions. Negative a* and L* values were not modified neither by altitude nor by light condition. Positive colour b* and C* values showed the same pattern of variation, being reduced in the two highest altitudes for all light conditions, as compared with 650 m. Hue angle (H) and colour index (CI) values point to a yellow / greenish colour in all treatments, with a slightly greater yellow component at 650 m as compared to the other two altitudes. Trigonelline showed one of the most striking responses, being markedly increased at the highest altitude, under MS (126%) and FS (170%). Caffeine and *p*-coumaric acid contents showed mostly non-significant changes, although a reduction of the latter was observed under MS and FS at 825 m. Caffeoylquinic acids 3-CQA and 4-CQA showed minor changes, with a tendency to lower values at 935 m, whereas the most abundant (5-CQA) tended to greater values at 835 or 935 m, all without differences between light conditions. The 4-FQA and 5-FQA were reduced at 935 m in comparison with 650 m. Moreover, both FQA isomers increased from DS to FS (mostly at 825 m). For the diCQA isomers no change was observed between light conditions, but all greatly declined at 835 and 935 m [1].

Conclusions & Perspectives:
In general, light (FS and shade by native trees) did not greatly and consistently modify the physical and chemical attributes of coffee quality. In contrast, altitude, associated with lower temperature, greater water availability through rainfall and fog, and extended fruit maturation period, was a major driver for those traits modification, likely improving coffee quality. As perspective, one intends to extend coffee plantations to higher altitude, having in mind a better quality of coffee beans.

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Validation of a New Coffee Cold Brew Method through Combined Central Location Tests and a Modified Conjoint Analysis and Focus Groups with Cold Brew Consumers and Brewers

Lim Lik Xian[1] (lxlim@ucdavis.edu), Diskin Christopher[2], Strogen April[2], Guinard Jean-Xavier[1]

[1] *UC Davis Coffee Center, University of California, Davis, California, USA* ; [2] *OXO, New York, USA*

Cold brew coffee is a fast-growing beverage category. The purpose of this research was to validate a new cold brew method through combined central location tests and a modified conjoint analysis and focus groups with cold brew consumers and brewers.

First, the acceptance of medium and dark roasted Colombian coffee brewed with the new cold brew method (NEW) was compared to that of the same coffees brewed with two market-leading methods (ML1 and ML2) in a central location test with 160 Gen Z and Millennial cold brew consumers. Consumers rated their liking for the coffees on the 9-point hedonic scale, the adequacy of color, flavor, acidity, roasted character and body on just-about-right (JAR) scales, used check-all-that-apply (CATA) from a list of 24 sensory and holistic attributes to describe the coffees, commented on what they liked and disliked about the coffees, and ranked the 3 coffees within each roast for preference. The flavor profile of the coffees was driven mostly by roast. Hedonic ratings were significantly higher for the dark roasts than the medium, with no difference among cold brew methods. There was no preference among the three brewing methods. Penalty-Lift Analysis of hedonic ratings versus CATA selections identified smooth, roasted, bitter and nutty as positive drivers of liking and smoky/burnt, earthy and bland as negative ones. Preference mapping uncovered 3 preference segments with the largest segment preferring the dark roasted coffees. A majority of consumers rated the flavor intensity of all 6 coffees as JAR. The acidity/sournessof all three medium roast coffees was rated as 'too high' by a majority of consumers, particularly NEW and ML1 coffees, yet the incurred penalty on their liking was negligible.

Second, 22 brewers of cold brew participated in a demonstration of the three methods, followed by a modified conjoint analysis (of the coffee-method combinations), and a focus group to assess their respective advantages and limitations. Coffees brewed with the 3 methods were liked equally, but the NEW coffee-method combination was liked best and judged easiest to use and fastest ($p<0.05$ or lower). Size, sustainability, not-as-messy, easy-to-clean and fun, pleasant mouthfeel but not your typical cold brew flavors were other attributes associated with the NEW method.

The combination of quantitative and qualitative consumer testing methodologies in this study showed consumer acceptance of both the coffees brewed with the NEW cold brew method and of the NEW cold brew method itself, thus paving the way for its successful launch.

Assessment of roasted coffee adulteration with coffee husks by gas chromatography and electronic tongue

Petronilho Sílvia[1, 2] (silviapetronilho@ua.pt), Loura Maria[1, 3], Coimbra Manuel A.[1], Passos Cláudia P.[1], Rudnitskaya Alisa[3]

[1] *LAQV-REQUIMTE, Chemistry Department, University of Aveiro, Aveiro, Portugal* ; [2] *CQ-VR, Chemistry Department, University of Trás-os-Montes & Alto Douro, Vila Real, Portugal* ; [3] *CESAM, Chemistry Department, University of Aveiro, Aveiro, Portugal*

Rationale:
Coffee is one of the most popular beverages worldwide, being an important product for the economic status of the countries involved in its production and commercialization. However, coffee is frequently adulterated for economic gains through the incorporation of low-cost materials in the coffee powder, such as coffee husks (also known as cascara obtained from the coffee cherry) [1]. Thereby, there is a need to adopt fast and reliable methodologies for the detection of coffee adulterations to ensure coffee quality.

Methods:
Medium roast Colombia Arabica coffee was mixed with coffee husks at different concentrations to evaluate the feasibility of using headspace solid-phase microextraction coupled to gas chromatography/mass spectrometry (HS-SPME/GC-MS) and electronic tongue in the detection of this adulteration.

Results:
HS-SPME/GC-MS allowed the detection of volatile compounds derived from the secondary plant metabolism in coffee husks and adulterated samples, suggesting that they can be used as adulterant markers in the brews. The results confirmed the feasibility of HS-SPME/GC-MS for adulterant detection down to 2% w/w of coffee husks while 5% (w/w) was the limit of the electronic tongue.

Conclusions & Perspectives:
This study showed that HS-SPME/GC-MS and electronic tongue can be used as simple and sensitive tools for adulteration detection in coffee brews at industrial level, although a fast screening can be achieved using electronic tongue while HS-SPME/GC-MS allowed the adulterant detection at the lower amount tested.

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Impact of superheated steam roasting process on the in-cup quality of espresso coffee brews

Severini Carla[1] (carla.severini@unifg.it), Derossi Antonio[2], Caporizzi Rossella[2], Chindapan, N.[3], Devahastin Sakamon[4]

[1] *Department DAFNE - Lab of Emerging Technology and Food Formulation, University of Foggia, Foggia, Italy, Italy* ; [2] *Department DAFNE - Lab of Emerging Technology and Food Formulation, University of Foggia, Foggia, Italy* ; [3] *Siam University, Thailand, Siam University, Thailand, Thailand, Thailand* ; [4] *Dept. Food Engineering, King Mongkut's University of Technology Thonburi, Thailand, Thailand*

Rationale:
Espresso coffee (EC) is one of the most appreciated beverages resulting from the extraction under high-pressure of roasted and ground beans. Although it originates in Italy, the beverage is now consumed all over the world, explaining the extensive research on the influence of coffee processing and preparation parameters on the overall quality of the beverage. Superheated steam (SHS) roasting is an innovative process that has proved to impact on several quality characteristics of coffee beans, with particular interest in aromatic, toxic and antioxidant characteristics. Limited information are still available on the chemical and aromatic properties of the brews. This study describes the physical properties of the beans and the quality of espresso coffee prepared by SHS roasting in comparison with those by hot air roasting.

Methods:
Arabica coffee beans (*Coffea arabica*) were roasted with SHS and hot air (HA) at three different temperatures to reach dark roasting levels. 2D/3D X-ray described the microstructure properties of roasted beans. The beans were ground and the coffee powder was characterized by using a laser particle size analyzer. EC of 25 mL was prepared by using 7 grams of powders by a professional EC machine . The quality of the EC was analyzed for physical (pH, acidity, total solids content, crema volume) and chemical properties (caffeine and total phenolics contents, antioxidant activity) by following the official and widely accepted protocols. Also, aromatic profiles with e-nose analysis were investigated and compared.

Results:
Differences in the microstructural properties of the roasted beans were interpreted. The beans roasted different temperatures affected the in-cup quality of coffee. Specifically, total phenolics content and antioxidant activity showed higher values in SHS-brews than HA-brews, especially at the lowest temperatures of roasting. Also, by comparing the two roasting processes, the aromatic profiles detected with the electronic nose and the physical-chemical composition of espresso coffees (titratable acidity, pH and total solids content) exibhited differences.

Conclusions & Perspectives:
The superheated steam processing of coffee is a valuable alternative method to roast green coffee beans, leading to comparable and, for some attributes, superior quality characteristics of the resulting coffee brew. In-depth analysis of the aromatic, bioactive and toxic compounds will be considered. Also, the characterization of SHS-brews obtained with different extraction methods demands further investigations. Finally, for industrial application of the proposed process, energy consumption and cost evaluation should be evaluated.

Genotype by environment interaction and stability of Ethiopian coffee (*Coffea arabica* L.) genotypes collected from Wollega Coffee growing areas for quality attributes

Weldemichael Getachew[1] (getachewweldemichael@gmail.com), Alamerew Sentayehu[2], Tulu Leta[3], Berecha Gezahegn[4]

[1] *Coffe and tea research program, EThiopian Institute of Agricultural Research, Jimma, Oromiya, Ethiopia* ; [2] *Crop process, EThiopian Institute of Agricultural Research, Holeta, Oromiya, Ethiopia* ; [3] *Plant biotechnology, National Agricultural Biotechnology Research Center, Holeta, Oromiya, Ethiopia* ; [4] *Horticulture and plant science, Jimma university, Jimma, Oromiya, Ethiopia*

Rationale:
As the quality of coffee is highly affected by environments, evaluation of genotypes for stability and performance under varying environmental conditions has become an essential part of the coffee quality breeding program. Despite the information on genotype by environment interaction and genetic variability is essential for the development of coffee cultivars with high coffee quality, this information is scant for Wollega-originated coffee types. The study was, therefore, conducted to assess the magnitude of GEI, estimate the variance component, and the stability of Wollega coffee genotypes for quality attributes.
Methods:
The experiment was conducted at Haru, Nedjo, and Mugi on 16 coffee genotypes using a randomized complete block design with three replications during the 2016 and 2017 crop seasons. Data on 12 important quality traits were recorded. The combined analysis of variance, estimation of variance components, and stability analyses were performed.
Results:
The combined analysis of variance indicated that the interaction between location, year, and genotype was significant (P<0.05) for aromatic intensity, acidity, flavor, overall coffee quality, and total coffee quality. Almost all coffee quality attributes had low PCV and GCV values (<10%). On the other hand, most of the coffee quality attributes such as acidity (87.34 %), overall coffee quality (70.59%), shape and make (69.07%), aromatic intensity (68.18%), body (65.52%), total coffee quality (61.71%), aromatic quality (59.46%) and flavor (58.57%) had higher heritability. Nevertheless, all of those traits showed low genetic advance values (<10%). Furthermore, the stability analysis identified G6 (W54/99) and G10 (W99/99) for acidity; G2 (W13/99) and G4 (W108/99) for flavor; G2 (W13/99), G4 (W108/99), and G12 (Haru 1) for overall quality and G4 (W108/99), G6 (W54/99) and G2 (W13/99) for total quality as relatively stable genotypes.
Conclusions & Perspectives:
In general, the study revealed the existence of GEI for coffee quality attributes. The study has also shown that there is a possibility of getting stable genotypes for each quality attribute. Moreover, it can also be concluded that coffee quality attributes cannot be improved with simple selection as all coffee quality attributes have low genetic advance.Therefore, it is recommended to use these stable genotypes for future coffee breeding programs and use heterosis breeding to improve the performance of each quality attribute. However, as the coffee quality is affected by the bean's biochemical content, the effects of GEI on the coffee bean's biochemical content should also be considered in future studies.

Effects of coffee-derived chlorogenic acids on postprandial serum triglyceride Levels. - A Randomized, double-blind, placebo-controlled, crossover study -

Iwai Kazuya[1] (kazuya-iwai@ucc.co.jp), Tanaka Aiko[2], Kagami-Katsuyama Hiroyo[2], Ariki Shingo[1], Morimoto Shiori[1], Nishihira Jyun[2]

[1] *R&D Department, UCC Ueshima Coffee Co., Ltd.,, Kobe, Hyogo, Japan* ; [2] *Hokkaido Information University, Ebetsu, Hokkaido, Japan*

Objective:
We evaluated the effects of coffee-derived chlorogenic acids on postprandial serum triglyceride (TG) levels in this randomized, double-blind, placebo-controlled, crossover study.
Methods:
24 healthy subjects with fasting serum TG levels ≧100 mg/dL and ≦149 mg/dL were randomly divided into two groups. Subjects ingested test food (containing 350 mg coffee derived chlorogenic acids) or placebo food (not containing coffee-derived chlorogenic acids) together with a high fat meal (lipid: 49 g). Serum TG levels was measured before and 1,2,3,4 and 6 hours after ingestion.
Results:
In the analysis of all subjects, postprandial serum TG levels did not differ signifi- cantly between the test food and the placebo food. However, in the subgroup with the maxi- mum serum concentration (Cmax) of TG ≧2200 mg/dL when ingested placebo food, in comparison with the placebo food, the test food significantly lowered the delta TG at 6 hours after ingestion and the Cmax of delta TG (each $P<0.05$). In addition, the test food lowered the incremental area under the curve (iAUC) values of TG ($P<0.10$). No adverse events attributable to the test food were observed throughout the study period.
Conclusion:
These results suggest that ingestion of coffee-derived chlorogenic acids suppresses the evaluation of postplandial serum TG levels in subjects with relative high postprandial serum TG levels.

Table of contents

LIST OF PARTICIPANTS

ABERKANE Hafid
Plant science unit
Nestlé
TOURS – FRANCE
hafid.aberkane@rd.nestle.com

ABRHA Getachew Weldemichael
Coffee and Tea research process
Ethiopian Institute of Agricultural Research
JIMMA – ETHIOPIA
getachewweldemichael@gmail.com

ADUGNA Girma
Horticulture and Plant Sciences
Jimma University
JIMMA – ETHIOPIA
girma.adugna@ju.edu.et

AGNOLETTI Bárbara Zani
Coffee Design
Federal Institute of Espírito Santo
ESPÍRITO SANTO – BRAZIL
barbara.za@hotmail.com

AKBAR Miftahur Rizqi
Plant Breeding
Indonesian Coffee and Cocoa Research Institute
JEMBER – INDONESIA
miftahur.ra@gmail.com

AKBAR Sholahuddin
Socio Techno-Economy
Indonesian Coffee and Cocoa Research Institute
JEMBER – INDONESIA
sholahuddinabr@gmail.com

ALI Wassu Mohammed
School of Plant Sciences
Haramaya University
HARAMAYA - OROMIA – ETHIOPIA
wasmoha@yahoo.com

ALMEIDA Julieta Andrea Silva de
Centro de Café 'Alcides Carvalho
Instituto Agronômico de Campinas
CAMPINAS – BRAZIL
julieta.almeida@sp.gov.br

ALPIZAR Edgardo
ECOM Nicaragua
MANAGUA – NICARAGUA
ealpizar@ecomtrading.com

ALUKA Pauline
Coffee Cocoa Variety Improvement and Management
National Agricultural Research Organisation - NARO - NaCORI
MUKONO – UGANDA
p.aluka2012@gmail.com

ALWORA Getrude
Plant Pathology
KALRO - Coffee Research Institute
RUIRU – KENYA
gedohal@yahoo.com

AMAN Nuhu Mbwebwe
Crop Improvement Research Program
Tanzania Coffee Research Institute
TaCRI
MOSHI – TANZANIA
nuhu.aman@tacri.or.tz

AMINI Rasool Khan
Saza Coffee
HITACHINAKA - IBARAKI – JAPAN
rasool.ameen@gmail.com

AMOA Jésus
Café - Cola / Agronomie
Centre National de Recherche Agronomique
MAN – CÔTE D'IVOIRE
amoapv@gmail.com

AMSALINGAM Roobak Kumar
Entomology
Central Coffee Research Institute
CHIKKAMAGALURU – INDIA
roobakkumar@gmail.com

ANGELO Paula CS
Embrapa Coffee
Embrapa
LONDRINA – BRAZIL
paula.angelo@embrapa.br

AOKI Toshiyuki
Ajinomoto AGF, Inc.
BIEN HOA - DONG NAI – VIET-NAM
toshiyuki_aoki@ajinomoto.com.vn

APIS Bartholomew
Research & Innovation Program / Agronomy Department
Coffee Industry Cooperation Limited
KAINANTU - EASTERN HIGHLANDS
PAPUA NEW GUINEA
bapis@cic.org.pg

ARRIETA-ESPINOZA Noel
San Francisco Bay Coffee
CARTAGO – COSTA RICA
neo2602@gmail.com

ASAWAPRECHA Sunida
R&D
Ajinomoto AGF, Inc.
BANGKOK – THAILAND
ningsunida@gmail.com

ASYIAH Iis Nur
Biology Education
University of Jember
JEMBER – INDONESIA
iisnaza.fkip@unej.ac.id

ATWIJUKIRE Evans
Value addition
National Coffee Research Institute
MUKONO – UGANDA
evans.atwijukire6@gmail.com

AZINHEIRA Helena
DCEB - CIFC
Instituto Superior de Agronomia
LISBOA – PORTUGAL
hmga@edu.ulisboa.pt

BAFEO Michelle
Breeding
Papua New Guinea Coffee Industry Corporation Limited
UKARUMPA - EASTERN HIGHLANDS PROVINC – PAPUA NEW GUINEA
mbafeo@cic.org.pg

BAI Xuehui
Dehong Tropical Agriculture Research Institute of Yunnan
RUILI – PEOPLE'S REPUBLIC OF CHINA
724180976@qq.com

BARRERA LEMUS Santos
Research and Development
World Coffee Rersearch
CALI – COLOMBIA
santos@worldcoffeeresearch.org

BARRETO-PEIXOTO Juliana
Laboratory of Bromatology and Hydrology
Faculty of Pharmacy - University of Porto
PORTO – PORTUGAL
jpeixoto@ff.up.pt

BEKELE Kifle Belachew
Coffee protection
Ethiopian Institute of Agricultural Research
JIMMA – ETHIOPIA
kiflekef@gmail.com

Table of contents

BENNETT Ruth
Migratory Bird Center
Smithsonian Institution
WASHINGTON – USA
bennettr@si.edu

BERNY Jorge
World Coffee Reserach
PORTLAND - OREGON – USA
jorge@worldcoffeeresearch.org

BERTRAND Benoît
BIOS/DIADE/COFFEEADAPT
Cirad
MONTPELLIER – FRANCE
bgbertrand3459@gmail.com

BIENABE Estelle
UMR Innovation
International Center for research in Agroforestry in Vietnam
TAY HO - HANOI – VIET-NAM
icraf-vietnam@cifor-icraf.org

BLISKA Flàvia
Coffee Center
Agronomic Institute
CAMPINAS – BRAZIL
flavia.bliska@sp.gov.br

BOLLEN Robrecht
Meise Botanic Garden
MEISE – BELGIUM
robrecht.bollen@plantentuinmeise.be

BONGERS Sandra
Technology & Training
Probat SE
EMMERICH AM RHEIN – GERMANY
s.bongers@probat.com

BOSSOLASCO Laurent
Sustainability
ECOM Vietnam
HO CHI MINH – VIET-NAM
lbossolasco@ecomtrading.com

BOTHA Cila
School of Chemical & Minerals Engineering
North-West University
POTCHEFSTROOM – SOUTH AFRICA
cila.botha@nwu.ac.za

BRIESEN Heiko
SVT - Process Systems Engineering
Technical University Munich
FREISING – GERMANY
heiko.briesen@tum.de

BROECKHOVEN Ieben
Dep. of Earth and Environmental Sciences
KU Leuven
LEUVEN – BELGIUM
ieben.broeckhoven@kuleuven.be

BROWNING David
Enveritas
OLD GREENWICH – USA
sam@enveritas.org

BYTOF Gerhard
Coffee Technology, Research & Development
Tchibo GmbH
HAMBURG – GERMANY
gerhard.bytof@tchibo.de

CAIXETA Eveline
Embrapa Café
Embrapa
VIÇOSA – BRAZIL
eveline.caixeta@embrapa.br

CALDEIRA VIEGAS Marcelo
Research & Development
IGC
CORNÉLIO PROCÓPIO - PARANÁ – BRAZIL
mviegas@iguacu.com.br

CANDEO FONTANINI Jose Italo
Research & Development
IGC
CORNÉLIO PROCÓPIO - PARANÁ – BRAZIL
italo@iguacu.com.br

CAO Cindy
Swiss Water Decaffeinated Coffee Inc.
DELTA – CANADA
ccao@swisswater.com

CARRÉRA Jéfyne
Departamento de Biologia
Universidade Federal de Lavras
LAVRAS - MINAS GERAIS – BRAZIL
jefynecarrera@gmail.com

CASAS Philippe
R&D
JDE Peet's
UTRECHT – THE NETHERLANDS
philippecasas@gmail.com

CHARRIER André
ASIC
SAINT CLEMENT DE RIVIERE – FRANCE
charrierandre@outlook.fr

CHEN Zhenjia
Cofffee Engineering Research Center of China
MANG – PEOPLE'S REPUBLIC OF CHINA
905088953@qq.com

CHERIERE Timothée
UMR ABSys
Cirad
MONTPELLIER – FRANCE
timothee.cheriere@cirad.fr

CHESEREK Jane
breeding
Coffee Research Institute
NAIROBI – KENYA
jane.cheserek@kalro.org

CHUNG Hsiao-Yen
Department of Food Science
National Taiwan Ocean University
KEELUNG CITY – REPUBLIC OF CHINA (TAIWAN)
choco.seanchong@gmail.com

CHUNG Hsiaoyen
Department of Food Science
National Taiwan Ocean University
KEELUNG CITY – REPUBLIC OF CHINA (TAIWAN)
choco.seanchong@gmail.com

CHUNHUA Zhu
Beijing Giant Technical Service Company
BEIJING – PEOPLE'S REPUBLIC OF CHINA
zchua910@126.com

CLEVE Nina
Fraunhofer Institute for Process Engineering and Packaging IVV
FREISING – GERMANY
nina.cleve@ivv.fraunhofer.de

COLOMBAN Silvia
Aromalab
illycaffè spa
TRIESTE – ITALY
silvia.colomban@illy.com

CORNUZ Maurin
Mane SEA
SINGAPORE – SINGAPORE
maurin.cornuz@mane.com

COUGHLIN James
Coughlin & Associates - Consultants
ALISO VIEJO – USA
jrcoughlin@cox.net

Table of contents

CRISAFULLI Paola
Biolab
illycaffè spa
TRIESTE – ITALY
paola.crisafulli@illy.com

CUNHA Rodrigo
Faculty of Medicine
University of Coimbra
COIMBRA – PORTUGAL
rcunha@fmed.uc.pt

DARRACQ Olivier
Coffee and cocoa
Nestlé
TOURS – FRANCE
olivier.darracq@rdto.nestle.com

DAS Divya Kallingapuram
Plant Breeding and Genetics
Central Coffee Research Institute
CHIKKAMAGALURU – INDIA
divyudas@gmail.com

DE ANGELIS Elisabetta
Aromalab
illycaffè spa
TRIESTE – ITALY
elisabetta.deangelis@illy.com

DEL TERRA Lorenzo
Biolab
illycaffè spa
TRIESTE – ITALY
lorenzo.delterra@illy.com

DELAHAIE Boris
UMR DIADE - CoffeeAdapt
Cirad
MONTPELLIER – FRANCE
boris.delahaie@cirad.fr

DESOBGO NGUEPI Yves Clyford
R&D
Demus S.p.A
TRIESTE – ITALY
cdesobgo@demus.it

DI BONAVENTURA Azzurra
Department of Agricultural, Food, Environmental and Animal Sciences
University of Udine
UDINE – ITALY
dibonaventura.azzurra@spes.uniud.it

DOS SANTOS GOMES Willian
Universidade Federal do Espírito Santo
VENDA NOVA DO IMIGRANTE
ES – BRAZIL
gwill.bio@gmail.com

DUEZ Camille
Coffee
Lallemand
BLAGNAC – FRANCE
cduez@lallemand.com

DUONG Benoit
UMR ABSys
Cirad
MONTPELLIER – FRANCE
benoit.duong@cirad.fr

ERCOLE Martina
illycaffè spa
TRIESTE – ITALY
martina.ercole@illy.com

FABELLA Jermaine
National Coffee Research, Development and Extension Center
Cavite State University
CAVITE CITY – PHILIPPINES
jermaine.fabella15@gmail.com

FABIANUS Reza
National Cooperative
JAKARTA – INDONESIA
reza.fabianus@gmail.com

FAHEEM Muhammad
Plant Protection
CABI
SERDANG - SELANGOR – MALAYSIA
m.faheem@cabi.org

FAINA Moreno
illycaffè spa
TRIESTE – ITALY
moreno.faina@illy.com

FARAH Adriana
Instituto de Nutrição
Universidade Federal do Rio de Janiero
RIO DE JANEIRO – BRAZIL
afarah@nutricao.ufrj.br

FARR Robert
Technical Solutions
Jacobs Douwe Egberts
BANBURY – UK
robert.farr@jdecoffee.com

FISK Ian
University of Nottingham
NOTTINGHAM – UK
ian.fisk@nottingham.ac.uk

FONCY-PENOT Evelyne
Fermentis
LILLE – FRANCE
e.fonchy-penot@fermentis.lesaffre.com

FUKUI Yasuhiro
T. Hasegawa CO.,LTD.
KAWASAKI - KANAGAWA – JAPAN
yasuhiro_fukui@t-hasegawa.co.jp

GAITÁN Alvaro
Cenicafé
Federacion Nacional de Cafeteros de Colombia
MANIZALES - CALDAS – COLOMBIA
director.cenicafe@cafedecolombia.com

GANESHARAO HALEMANE Seetharama
Central Coffee Research Institute
CHIKKAMAGALURU – INDIA
seetharamhg@gmail.com

GATARAYIHA Celestin
Inter-African Coffee Organisation - IACO
ABIDJAN – CÔTE D'IVOIRE
cgatarayiha@iaco-oiac.org

GIANG Pham Hoang
The Centro Internacional De Agricultura Tropical - CIAT
HANOI – VIET-NAM
linh.nguyen@cgiar.org

GIRMA Sintayehu
Coffee improvement
Agricultural research
MECHARA – ETHIOPIA
girmasintayehu@gmail.com

GLOESS Alexia N.
Development Lab
Private
RICHTERSWIL – SWITZERLAND
alexia.gloess@gmx.ch

GOLE Tadesse Woldemariam
Environment and Coffee Forest Forum
ADDIS ABABA – ETHIOPIA
twgole@gmail.com

GUERRA-GUIMARÃES Leonor
Instituto Superior de Agronomia
Universidade de Lisboa
LISBOA – PORTUGAL
leonorguimaraes@edu.ulisboa.pt

GUINARD Jean-Xavier
UC Davis Coffee Center
University of California
DAVIS – USA
jxguinard@ucdavis.edu

Table of contents

GUO Tieying
Dehong Tropical Agriculture Research Institute of Yunnan
RUILI – PEOPLE'S REPUBLIC OF CHINA
arabicacoffee@qq.com

GUYOT Romain
DIADE
IRD
MONTPELLIER – FRANCE
romain.guyot@ird.fr

HAGOS Legese
Ethiopian Institute of Agricultural Research
SEBATA – ETHIOPIA
legehagos@gmail.com

HAILELIUEL Natanim
Laboratory Technician
Cup of Excellence
ADDIS ABABA – ETHIOPIA
natanimhaileliuel@gmail.com

HAMANA Yoshiki
R&D
Ajinomoto AGF, Inc.
TOKYO – JAPAN
yoshiki.hamana.pd6@asv.ajinomoto.com

HANZAWA Taku
Research & Development
UCC Ueshima Coffee Co., Ltd
KOBE – JAPAN
taku-hanzawa@ucc.co.jp

HARUTAKA Araki
Department of Medical Engineering, Faculty of Medicine
Morinomiya University of Medical Sciences
OSAKA – JAPAN
harutakaaraki@gmail.com

HUMPHREY Tania
R&D
World Coffee Research
PORTLAND - OREGON – USA
tania@worldcoffeeresearch.org

INKAEW Prachak
Applied Chemistry Program
Mae Fah Luang University
MUANG - CHIANG RAI – THAILAND
prachak.ink@mfu.ac.th

ISHIWAKI Tomohiro
S. Ishimitsu & Co., Ltd
KOBE – JAPAN
t-ishiwaki@ishimitsu.co.jp

ITO Dhalton
Plant Protection Department / Laboratory of Nematology
Rural Development Institute of Parana
LONDRINA – BRAZIL
ito@idr.pr.gov.br

IWABE Honoka
Department of Medical Engineering, Faculty of Medi
Morinomiya University of Medical Sciences
OSAKA – JAPAN
2021bme007@s.morinomiya-u.ac.jp

IWAI Kazuya
R&D Department
UCC Ueshima Coffee Co., Ltd
KOBE – JAPAN
kazuya-iwai@ucc.co.jp

JEUNE Wesly
Agronomes et Vétérinaires Sans Frontières (AVSF)
PÉTION-VILLE - OUEST – HAÏTI
w.jeune@avsf.org

JOËT Thierry
DIADE
IRD
MONTPELLIER – FRANCE
thierry.joet@ird.fr

JUNG Yonghoon
Dongsuh Foods Corp.
INCHEON – REPUBLIC OF KOREA
yhjung@dongsuh.co.kr

K N Aswathi
Plantation Products, Spices and Flavor Technology
CSIR-Central Food Technological Research Institute
MYSURU - KARNATAKA – INDIA
aswathimanoharan24@gmail.com

KAKIUCHI Misako
Research & Development Department
UCC Ueshima Coffee Co., Ltd
KOBE – JAPAN
misako-kakiuchi@ucc.co.jp

KAMINARI KONNO Karina
Research & Development
IGC
CORNÉLIO PROCÓPIO - PARANÁ – BRAZIL
karina@iguacu.com.br

KATH Jarrod
Ecology and Conservation
University of Southern Queensland
TOOWOOMBA – AUSTRALIA
jarrod.kath@usq.edu.au

KATHURIMA Cecilia
Chemistry
KALRO - Coffee Research Institute
RUIRU – KENYA
cecilia.kathurima@kalro.org

KAWUKI Robert
World Coffee Research
KAMPALA – UGANDA
robert@worldcoffeeresearch.org

KEITH Lisa
USDA - ARS - PBARC
HILO – USA
lisa.keith@usda.gov

KHONGPHINITBUNJONG Kitiphong
School of Science
Mae Fah Luang University
MUANG - CHIANG RAI – THAILAND
kitiphong.kho@mfu.ac.th

KIWELU Leonard
Special Projects and Business Unit
Tanzania Coffee Research Institute
TaCRI
MOSHI - KILIMANJARO – TANZANIA
leonard.kiwelu@tacri.org

KOELLING-SPEER Isabelle
Food Chemistry
Technical University of Dresden
DRESDEN – GERMANY
isabelle.koelling-speer@chemie.tu-dresden.de

KOZIOROWSKI Thomas
R&D
Probat AG
EMMERICH AM RHEIN – GERMANY
t.koziorowski@probat.com

KRAFT Kraig
World Coffee Research
PORTLAND - OREGON – USA
kraig@worldcoffeeresearch.org

LANTZ Ingo
CT Coffee Technology
Tchibo GmbH
HAMBURG – GERMANY
ingo.lantz@tchibo.de

Table of contents

LARA-ESTRADA Leonel
Research Unit Sustainability and Global Change
University of Greenwich
CHATHAM – UK
ll8050e@gre.ac.uk

LATVAKANGAS Sampo
Paulig
HELSINKI – FINLAND
sampo.latvakangas@paulig.com

LE Hoai
R&D
Ajinomoto AGF, Inc.
HO CHI MINH – VIET-NAM
hoai_ltm@ajinomoto.com.vn

LE Huu Thang
Innovation
Cafe Outspan Vietnam
BEN LUC - LONG AN – VIET-NAM
thang.le@ofi.com

LEE Jongin
Dongsuh Foods Corp.
INCHEON – REPUBLIC OF KOREA
jinlee@dongsuh.co.kr

LEFEBVRE Florent
Nestlé Nespresso
ROMONT – SWITZERLAND
florent.lefebvre-pautigny@nespresso.com

LEITÃO Antonio
Instituto Superior de Agronomia
OEIRAS – PORTUGAL
antonioleitao@isa.ulisboa.pt

LELOUP Valérie
Nestlé
ORBE – SWITZERLAND
valerie.leloup@rdor.nestle.com

LESUEUR Didier
UMR Eco&Sols
Cirad
HANOI – VIET-NAM
d.lesueur@cgiar.org

LI Jinhong
Dehong Tropical Agriculture Research Institute of Yunnan
RUILI – PEOPLE'S REPUBLIC OF CHINA
lijinhong@dtari.org.cn

LIANG Jiexin
Food Science and Technology
University of California, Davis
DAVIS – USA
jxliang@ucdavis.edu

LIANG Jingsi
Department of Agronomy and Biological Sciences
Dehong Teacher's Collegue
MANGS - YUNNAN – PEOPLE'S REPUBLIC OF CHINA
905088983@qq.com

LIBERTO Erica
Department of Drug Science and Technology
University of Turin
TORINO – ITALY
erica.liberto@unito.it

LIM Lik Xian
UC Davis
DAVIS – USA
lxlim@ucdavis.edu

LONZARICH Valentina
Aromalab
illycaffè spa
TRIESTE – ITALY
valentina.lonzarich@illy.com

LOUZADA PEREIRA Lucas
Coffee Design
Instituto de Educação, Ciência e Tecnologia
ESPÍRITO SANTO – BRAZIL
lucaslozada@hotmail.com

MACHADO Marlene
Faculty of Pharmacy - University of Porto
PORTO – PORTUGAL
marlenemachado753@gmail.com

MADHIHALLI SHANMUKHAPPA Uma
Central Coffee Research Institute
CHIKKAMAGALURU – INDIA
umaccri@gmail.com

MAGESA Jeremiah
Technology Transfer & Advocacy
Tanzania Coffee Research Institute - TaCRI
MOSHI - KILIMANJARO – TANZANIA
jeremiah.magesa@tacri.org

MAGINA Fredrick
Good Agricultural Practices Research Programme
Tanzania Coffee Research Institute - TaCRI
MOSHI - KILIMANJARO – TANZANIA
fredrick.magina@tacri.org

MALVICINI Gian Luca
Coffee Procurement Dept.
illycaffè spa
TRIESTE – ITALY
gianluca.malvicini@illy.com

MAQSALINA Marich Nur
Department of Plant Protection
IPB University
BOGOR – INDONESIA
marichmaqsalina@apps.ipb.ac.id

MARCEL Kode
Medical Research Institute
DOUALA – CAMEROON
kodemarcel.md@gmail.com

MARKOVÁ Anna
Czech University of Life and Science Sucafina
PRAGUE – CZECH REPUBLIC
markova.anne@gmail.com

MARO Godsteven
Good Agricultural Practices Research
Tanzania Coffee Research Institute TaCRI
MOSHI - KILIMANJARO – TANZANIA
godsteven.maro@tacri.org

MARRACCINI Pierre
UMR DIADE
Cirad
MONTPELLIER – FRANCE
marraccini@cirad.fr

MARTINS Joana
Department of Earth Sciences
NOVA School of Science and Technology
FCT NOVA
CAPARICA – PORTUGAL
jis.martins@campus.fct.unl.pt

MARTIZANO Jay
Chemistry
University of the Philippines Visayas
ILOILO – PHILIPPINES
jomartizano1@up.edu.ph

MATSUBA Satoru
Technical Research and Development Institute
Ajinomoto AGF, Inc.
KAWASAKI - KANAGAWA – JAPAN
satoru.matsuba.4cb@agf.co.jp

MATSUMOTO Tracie
TPGRDRU
USDA - ARS - PBARC
HILO – USA
tracie.matsumoto@usda.gov

Table of contents

MBWAMBO Suzana
Tanzania Coffee Research Institute
TaCRI
MOSHI – TANZANIA
suzana.mbwambo@tacri.org

MERGA TEMESGEN Dawit
Plant Breeding
Ethiopian Institute of Agricultural Research
JIMMA – ETHIOPIA
dawitmerga@gmail.com

MILLET Claude Patrick
UMR DIADE
Cirad
MONTPELLIER – FRANCE
claudepatrickmillet@gmail.com

MONYO Harrison
Soil Fertility
Tanzania Coffee Research Institute
TaCRI
MOSHI – TANZANIA
harrison.monyo@tacri.org

MORAIS Heverly
Rural Development Institute of Parana
LONDRINA – BRAZIL
heverlymorais@gmail.com

MOREIRA DA SILVA Fábio
Engenharia Agrícola
Universidade Federal de Lavras
LAVRAS - MINAS GERAIS – BRAZIL
famsilva@ufla.br

MORÈRE Pierre
Ecology and History
Aix Mareille University
DALAT – VIET-NAM
pierre.morere@univ-amu.fr

MOUEN BEDIMO Joseph Aubert
Cabinet d'Expertise en Recherche et Conseils Agricoles
YAOUNDÉ – CAMEROON
josephmouen@yahoo.fr

MUBARAK Aidilla
Faculty of Fisheries and Food Science
Universiti Malaysia Terengganu
KUALA NERUS – MALAYSIA
aidilla@umt.edu.my

MUGGIA Paola
Innovation & Development
illycaffè spa
TRIESTE – ITALY
paola.muggia@illy.com

MUGO Harrison
Coffee Research Institute
KALRO - Coffee Research Institute
RUIRU – KENYA
mugohmu@yahoo.com

MUNISWAMI Sudha
Research Department
Coffee Board Of India
CHIKKAMAGALURU – INDIA
sudhaccri@gmail.com

MURAOKA Minami
Morinomiya University of Medical Sciences
OSAKA – JAPAN
2021bme063@s.morinomiya-u.ac.jp

MVUYEKURE Simon Martin
Traditional Export Crops Programme
Rwanda Agriculture Board
KIGALI – RWANDA
msmartin202@gmail.com

MWAKABUTA Twisege
Technology Transfer and Training
Tanzania Coffee Research Institute
TaCRI
MOSHI - MAIN LAND – TANZANIA
twisemwakabuta@yahoo.com

MYERS Roxana
Nematology
USDA - ARS - PBARC
HILO – USA
roxana.myers@usda.gov

MYRIE Ameka
University of Regensburg
REGENSBURG – GERMANY
ameka.myrie@ur.de

NAGAI Chifumi
Hawaii Agriculture Research Center
KUNIA – USA
cnagai@harc-hspa.com

NAKAI Mari
R&D Management Center
S. Ishimitsu & Co., Ltd
SHINAGAWA-KU - TOKYO – JAPAN
m_nakai@tacr.co.jp

NAKAMURA Sunao
Suntory Beverage & Food
KAWASAKI - KANAGAWA – JAPAN
sunao_nakamura@suntory.co.jp

NAVARINI Luciano
illycaffè spa
TRIESTE – ITALY
luciano.navarini@illy.com

NEHLIG Astrid
INSERM
STRASBOURG – FRANCE
astrid.nehlig@gmail.com

NEILSON Jeffrey
University of Sydney
DARLINGTON - NSW – AUSTRALIA
jeffrey.neilson@sydney.edu.au

NGUEN Van Long
Deakin University/Cirad/CIAT
HANOI – VIET-NAM
s222117312@deakin.edu.au

NGUYEN Minh Phuong
CIAT
HANOI – VIET-NAM
p.m.nguyen@cgiar.org

NGUYEN Thao Ly
Pharmacologie de sécurité
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
HANOI – VIET-NAM
thaolyn97@gmail.com

NGUYEN Tri Kien
The Centro Internacional de Agricultura Tropical - CIAT
HANOI – VIET-NAM
k.t.nguyen@cgiar.org

NGUYEN HOAI Thuong
Innovation
Cafe Outspan Vietnam
BEN LUC - LONG AN – VIET-NAM
hoaithuong.nguyen@ofi.com

NGUYEN VAN Trung
Cafe Outspan Vietnam
LONG AN – VIET-NAM
phong.quach@ofi.com

NILTHONG Somrudee
School of Science
Mae Fah Luang University
MUANG - CHIANG RAI – THAILAND
somrudee@mfu.ac.th

ODENY Danstan
Agronomy
Kenya Agricultural and Livestock Organization - Coffee Research Institute
RUIRU – KENYA
odeny.dan@gmail.com

Table of contents

OJO Afolabi Micheal
Akinade Nigeria Limited
IKOTUN - LAGOS – NIGERIA
akinadeniglimited@aol.com

OLADOKUN Yetunde Olasimbo Mary
Cocoa Research Institute of Nigeria
IBADAN – NIGERIA
yetunde.oladokun@gmail.com

OLIVEIRA Emanuele
Coffee Design Group
Federal Institute of Espírito Santo
VENDA NOVA DO IMIGRANTE – BRAZIL
emanuele.oliveira@ifes.edu.br

OPITZ Sebastian
Zurich University of Applied Sciences
ZHAW
WÄDENSWIL – SWITZERLAND
opit@zhaw.ch

OUTINEN-LAHTI Mari
Product Development
Paulig
HELSINKI – FINLAND
mari.outinen-lahti@paulig.com

OWATWORAKIT Amorn
Mae Fah Luang University
MUANG - CHIANG RAI – THAILAND
amorn@mfu.ac.th

OWUSU DANQUAH Eric
Crops for Nutrition and Health
The Alliance of Bioversity International and CIAT
VIENTIANE - VIETNAM – LAO PDR
linh.nguyen@cgiar.org

PAPPO Emily
Migratory Bird Center
Smithsonian Institution
WASHINGTON – USA
bennettr@si.edu

PARTELLI Fábio Luiz
DCAB
Federal University of Espírito Santo
SÃO MATEUS – BRAZIL
partelli@yahoo.com.br

PASSOS Cláudia P.
LAQV/REQUIMTE
Department of Chemistry
University of Aveiro
AVEIRO – PORTUGAL
cpassos@ua.pt

PELLEGRINO Gloria
R&D
Luigi Lavazza SpA
TORINO – ITALY
gloria.pellegrino@lavazza.com

PEREIRA Luiz Filipe
Plant Biotech Lab
Embrapa
LONDRINA – BRAZIL
filipe.pereira@embrapa.br

PEROTTI Ermanno
Trading
Sucafina
HO CHI MINH – VIET-NAM
epe@sucafina.com

PETCHKHAO Siriluk
R&D
Ajinomoto AGF, Inc.
BANGKOK – THAILAND
siriluk.petchkhao.s6u@asv.ajinomoto.com

PETERSON Devin
Food Science & Technology
The Ohio State University
COLUMBUS - OHIO – USA
peterson.892@osu.edu

PETRACCO Marino
Research
illycaffè spa
TRIESTE – ITALY
doctor.marinopetracco@gmail.com

PETRONILHO Sílvia
LAQV, Chemistry Department
University of Aveiro
AVEIRO – PORTUGAL
silviapetronilho@ua.pt

PHONG Quach
Cafe Outspan Vietnam
LONG AN – VIET-NAM
phong.quach@ofi.com

PIERL Dennis
Institute of Automation Technology
University of Bremen
BREMEN – GERMANY
dpierl@iat.uni-bremen.de

PIETERSEN Corné
Plant-Microbe Interactions
Utrecht University
UTRECHT – THE NETHERLANDS
c.m.j.pieterse@uu.nl

POIROT Pierre
Lallemand
BLAGNAC – FRANCE
ppoirot@lallemand.com

POISSON Luigi
Science & Technology
Société des Produits Nestlé SA
ORBE – SWITZERLAND
luigi.poisson@rdor.nestle.com

POLONINI MORELI Aldemar
Coffee Design
Instituto de Educação, Ciência e Tecnologia
ESPÍRITO SANTO – BRAZIL
aldemarpolonini@gmail.com

PONCET Valérie
UMR DIADE
IRD
MONTPELLIER – FRANCE
valerie.poncet@ird.fr

QUDRI Nuzul
World Coffee Research
BANDA ACEH – INDONESIA
nuzul@worldcoffeeresearch.org

RAGO Daba Etana
Environmental Management
Ibadan University
JIMMA – ETHIOPIA
dabaetana2018@gmail.com

RAHN Anja
JDE Peet's
VOLENICE – CZECH REPUBLIC
curious.about.coffee.science@gmail.com

RAMADHANI Fatuma
Tanzania Coffee Research Institute
TaCRI
KILIMANJARO – TANZANIA
fatumajumapili09@gmail.com

RAMALHO José C.
Instituto Superior de Agronomia
OEIRAS – PORTUGAL
cochichor@mail.telepac.pt

RAMIREZ Ludovico
World Coffee Research
PORTLAND - OREGON – USA
jun@worldcoffeeresearch.org

RAMIREZ-BUILES Victor Hugo
Yara Research Center
Yara International
DÜLMEN - NRW – GERMANY
victor.ramirez@yara.com

Table of contents

REVI Helen
R&D
Purity Coffee
GREENVILLE – USA
ildi@puritycoffee.com

RIGAL Clément
UMR System
Cirad
MONTPELLIER – FRANCE
clement.rigal@cirad.fr

RIVERA PALACIO Juan Camilo
Leibniz-Centre for Agricultural Landscape Research - ZALF
MÜNCHEBERG – GERMANY
juancamilo.rivera@zalf.de

RODOLFO Robert
Project Leader Flavor Profiling of Robusta Coffee
Kalinga State University
KALINA – PHILIPPINES
rarodolfo@ksu.edu.ph

RODRIGUES Ana
PlantStress and Biodiversity Lab, Forest Research
Instituto Superior de Agronomia
LISBOA – PORTUGAL
anadr@isa.ulisboa.pt

RYOTA Inoue
Department of Medical Engineering, Faculty of medi
Morinomiya University of Medical Sciences
OSAKA – JAPAN
ryoutainoue243@gmail.com

SAENGRAYAP Rattapon
School of Agro-Industry
Mae Fah Luang University
MUANG - CHIANG RAI – THAILAND
rattapon.sae@mfu.ac.th

SAENGSAI Weerakorn
Department of Agriculture
Khon Kaen Field Crops Research Center
KHON KAEN – THAILAND
weerakorn.saengsai@gmail.com

SAITO Shuhei
Suntory Beverage & Food
KAWASAKI - KANAGAWA – JAPAN
shuhei_saito@suntory.co.jp

SALISBURY Andrew
Purity Coffee
ATLANTA - GEORGIA – USA
andrew@puritycoffee.com

SALVADOR Henzo
Federal University of Espírito Santo
SÃO MATEUS – BRAZIL
henzosalvador@hotmail.com

SANTORO Patricia
IDR-Parana
LONDRINA – BRAZIL
patriciasantoro@idr.pr.gov.br

SARZYNSKI Thuan
DIADE
Cirad
HO CHI MINH – VIET-NAM
thuan.sarzynski@cirad.fr

SCALABRIN Simone
Technology Services
Istituto di Genomica Applicata
UDINE – ITALY
sscalabrin@igatechnology.com

SCHMIEDER Benedikt
Professorship Biothermodynamik
Technical University Munich
FREISING – GERMANY
benedikt.schmieder@tum.de

SERA Gustavo Hiroshi
Plant Breeding
Instituto de Desenvolvimento Rural do Paraná - IAPAR-EMATER
LONDRINA – BRAZIL
gustavosera@idr.pr.gov.br

SERA Tumoru
Plant Breeding
Instituto de Desenvolvimento Rural do Paraná - IAPAR-EMATER
LONDRINA – BRAZIL
tsera01@gmail.com

SERITO Bianca
Luigi Lavazza SpA
TORINO – ITALY
bianca.serito@lavazza.com

SEVERINI Carla
Agriculture, Food, Natural Resourches and Engineer
University of Foggia
FOGGIA – ITALY
carla.severini@unifg.it

SHIOJIRI Atsushi
Ajinomoto AGF, Inc.
SHIBUYA-KU - TOKYO – JAPAN
atsushi.shiojiri.bk5@agf.co.jp

SHRINER Suzanne
Synergistic Hawaii Agriculture Council
HILO – USA
info@shachawaii.org

SILVA Felipe
Inovação em Mecanização Agrícola
Ceifa Ltda.
Federal University of Lavras
LAVRAS - MINAS GERAIS – BRAZIL
felipe.oliveira@ufla.br

SILVA Maria do Céu
CIFC- Centro de Investigação das Ferrugens do Cafe
Universidade de Lisboa
Instituto Superior de Agronomia
OEIRAS – PORTUGAL
mariaceusilva@isa.ulisboa.pt

SPEER Karl
Food Chemistry
Technical University of Dresden
DRESDEN – GERMANY
speerrkarl@gmail.com

SSEREMBA Godfrey
Coffee and Cocoa Variety Improvement Programme
National Coffee Research Institute
MUKONO – UGANDA
gsseremba16@gmail.com

STEENHOF Vincent
Jacobs Douwe Egberts
UTRECHT – THE NETHERLANDS
vincent.steenhof@jdecoffee.com

STOFFELEN Piet
Meise Botanic Garden
MEISE – BELGIUM
piet.stoffelen@plantentuinmeise.be

SUBRAMANIAN Siva
Innovation
Olam Food Ingredients
WILLOWBROOK – USA
siva.subramanian@ofi.com

SUGGI LIVERANI Furio
Ernesto Illy Foundation
TRIESTE – ITALY
furio.suggi@fondazioneilly.org

SUGIURA Motohiko
Technology Development Dpt.
S. Ishimitsu & Co., Ltd
TOKYO – JAPAN
m-sugiura@ishimitsu.co.jp

Table of contents

SUMIRAT Ucu
Plant Breeding
Starbucks Farmer Support Center
JEMBER – INDONESIA
usumirat@starbucks.com

SUNARHARUM Wenny
Food Science and Biotechnology
Universitas Brawijaya
MALANG – INDONESIA
wbsunarharum@ub.ac.id

SUZUKI Taroh
Saza Coffee
HITACHINAKA - IBARAKI – JAPAN
suzuki_taroh@mac.com

SUZUKI Tomonori
Suntory Beverage & Food
13-2 IMAIKAMI-CHO, NAKAHARA-KU,
KAWA – JAPAN
tomonori_suzuki@suntory.co.jp

TADESSE Minda
Irrigation agronomy
Ethiopian Institute of Agricultural Research
JIMMA – ETHIOPIA
mindat9@gmail.com

TAN Kevin Neil
Chemistry Department
De La Salle University-Manila
MANILA – PHILIPPINES
kevin_neil_tan@dlsu.edu.ph

TANGTRAKULWANICH Khanobporn
Bilogical Science
School of Science, Mae Fah Luang
University
MUANG - CHAING RAI – THAILAND
khanobporn.tan@mfu.ac.th

TAPACA Inocencia
Forest Research Center
Instituto Superior de Agronomia
LISBOA – PORTUGAL
inoctapaca@gmail.com

TEIXEIRA Aldir
Laboratório
Experimental Agricola do Brasil
SÃO PAULO – BRAZIL
aldir.teixeira@illy.com

TOBIAS Peri
University of Sydney
CAMPERDOWN – AUSTRALIA
peri.tobias@sydney.edu.au

TRAN Ngoc
International Center for research in
Agroforestry in Vietnam
TAY HO - HANOI – VIET-NAM
t.ngoc@cifor-icraf.org

TSUJI Yoshihiro
Department of Medical Engineering
Morinomiya University of Medical
Sciences
OSAKA – JAPAN
yoshihiro_tsuji@morinomiya-u.ac.jp

TÜCK Sebastian
Research & Innovation
Probat AG
EMMERICH AM RHEIN – GERMANY
s.tueck@probat.com

TURELLO Luca
Coffee procurement
illycaffè spa
TRIESTE – ITALY
luca.turello@illy.com

UNO Katsuya
R&D Division/Flavor laboratory/
Department 4
Takasago International Corporation
1-4-11 NISHIYAWATA, HIRATSUKA CITY
- – JAPAN
katsuya_uno@takasago.com

VAAST Philippe
General Direction
Cirad
BOGOTA – COLOMBIA
philippe.vaast@cirad.fr

VAN ASTEN Piet
Coffee division
OFI
SINGAPORE – SINGAPORE
piet.vanasten@ofi.com

VAN DAM Rob
Department of Exercise and Nutrition
Sciences
George Washington University
WASHINGTON – USA
rvandam@gwu.edu

VAN DER VOSSEN Herbert
Former ASIC Board member
VENHUIZEN – THE NETHERLANDS
herbert.vandervossen@quicknet.nl

VI Bao Tram
DIADE
IRD
MONTPELLIER – FRANCE
vbt576@gmail.com

WANG Ming-Li
Hawaii Agriculture Research Center
KUNIA – USA
mwang@harc-hspa.com

WARNECKE Birgit
Deutscher Kaffeeverband e.V.
HAMBURG – GERMANY
warnecke@kaffeeverband.de

WATLA-IAD Kanchana
Applied Chemistry
School of Science, Mae Fah Luang
University
MUANG - CHIANG RAI – THAILAND
kanchana.wat@mfu.ac.th

WAYA Lemi
Coffee Breeding
Ethiopian Institute of Agricultural Research
JIMMA – ETHIOPIA
lbeksisa@gmail.com

WEGARI Adisu
Plant protection
Oromia Agricultural Research Institute
MECHARA – ETHIOPIA
wegariaddisu@gmail.com

WIBOWO Ari
Plant Breeding and Biotechnology
Indonesian Coffee and Cocoa
Research Institute
JEMBER – INDONESIA
ariwibowo.iccri@gmail.com

WINTER Carsten
Sales
Probat AG
EMMERICH AM RHEIN – GERMANY
c.winter@probat.com

WINTERMANS Paul
PlantLab
'S-HERTOGENBOSCH
THE NETHERLANDS
pwintermans@plantlab.nl

WONGSAKUL Sirirung
Mae Fah Luang University
MUENG - CHIANG RAI – THAILAND
sirirung@mfu.ac.th

Table of contents

XU Qing
Ajinomoto AGF, Inc.
SHANGHAI
PEOPLE'S REPUBLIC OF CHINA
qing_xu@ajinomoto.com.cn

YAMAMURA Kenji
Technical Research and Development Institute - Ajinomoto AGF, Inc.
MINAMITAMAGAKI-CHO
SUZUKA-SHI – JAPAN
kenji.yamamura.ey6@agf.co.jp

YEPES Marcela
Plant Pathology and Plant Microbe Biology Section - Cornell University
School of Integrated Plant Science
GENEVA – USA
my11@cornell.edu

YERETZIAN Chahan
Life Sciences, Institute of Chemistry & Biotechnology - Zurich University of Applied Sciences - ZHAW
WÄDENSWIL – SWITZERLAND
yere@zhaw.ch

YOUSEFI Ali
Trading
Sucafina
ANTWERP – BELGIUM
ali@sucafina.com

YU Qingyi
Tropical Plant Genetic Resources and Disease Research
USDA - ARS - PBARC
HILO – USA
qingyi.yu@usda.gov

ZENG Xiaolan
Ajinomoto AGF, Inc.
SONGJIANG - SHANGHA
PEOPLE'S REPUBLIC OF CHINA
xiaolan_zeng@ajinomoto.com.cn

ZHANG Haiya
ECOM China
PU'ER - YUNNAN
PEOPLE'S REPUBLIC OF CHINA
haiya.zhang@ecomtrading.com

ZHAO Guoxi
Dehong Emotion Coffee Co ltd
LONGYANG DISTRICT, BAOSHAN CITY
PR CHINA
905088983@qq.com

ZIMMERMANN Ralf
Photonion GmbH and Chair of Analytical Chemistry
University of Rostock (and HMGU)
ROSTOCK – GERMANY
ralf.zimmermann@uni-rostock.de

Table of contents

LIST OF SPONSORS

Detech Coffee
8 Ton That Thuyet, My Dinh 2 ward,
Nam Tu Liem district
HANOI – VIETNAM
+84 98 684 08 08
info@detechcoffee.com
https://detechcoffee.vn/en/

IllyCaffè
Production and marketing of coffee products.
Via Flavia, 110
34147 TRIESTE – ITALY
+39 04 03 89 01 11
info@illy.com
www.illy.com

ISIC - Coffee & Health
Institute for Scientific Information on Coffee.
Van Boetzelaerlaan 21
2581 AA THE HAGUE - THE NETHERLANDS
isic@isic.coffee.org
www.coffeeandhealth.org/about-isic

Luigi Lavazza Societa Per Azion
Strada Settimo, 410
IT-10156 TORINO - ITALY
isic@isic.coffee.org
www.coffeeandhealth.org/about-isic

Nespresso
Route de Lausanne 2
1680 ROMONT – SWITZERLAND
www.nestle-nespresso.com

Nestlé
Société des Produits Nestlé S.A.
Nestlé Product Technology Centre Coffee
Route de Chavornay 3
1350 ORBE – SWITZERLAND
www.nestle.fr

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